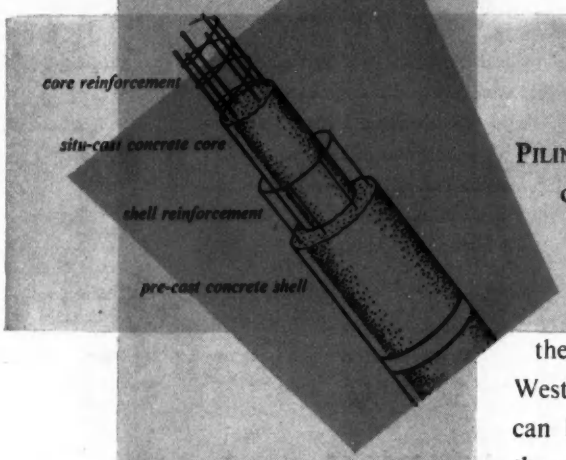
The Engineer

DECEMBER 21, 1956 28 ESSEX ST., STRAND, LONDON, W.C.2 TWO SHILLINGS

UNIVERSITY OF MICHIGAN

ENGINEERING LIBRARY

Worth remembering....



PILING HAS a significant advantage over all other types of foundation, particularly where heavy industrial structures are to be built—it gives a rational basis for the calculation of stability and is therefore an insurance against failure. In West's Shell Piling System, bearing capacity can be calculated and the pile is driven to the correct dynamic "set", thus ensuring its stability. The method successfully combines the pre-cast and cast-in-situ systems of piling. A pre-cast reinforced concrete sectional outer shell only is driven, the reinforced concrete core being cast in-situ after driving is completed. The firmness of the positively driven pile is retained, yet there is no fatigue in the pile core. The table below gives dimensions of shells and maximum loads per pile.

External dia.	Core dia.	Shell length	*Max. load tons
20 in.	15 in.	3 ft 0 in.	70—100
17½ in.	12 in.	3 ft 0 in.	50—60
14½ in.	10⅞ in.	4 ft 0 in.	30—40

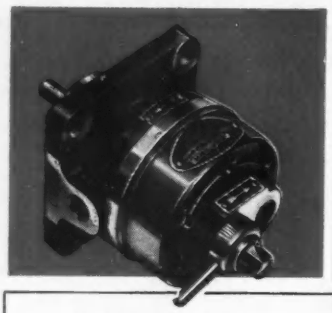
* *Depending on length of pile and strata conditions*

Please write for our latest publications

WEST'S SHELL PILING SYSTEM

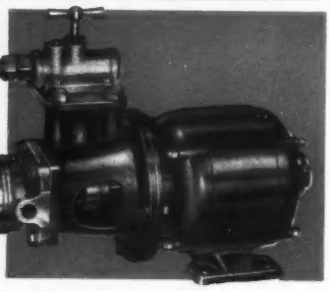
WEST'S PILING & CONSTRUCTION COMPANY LIMITED
FOUNDATION SPECIALISTS . DESIGN AND CONSTRUCTION IN REINFORCED CONCRETE
BATH ROAD, HARMONDSWORTH, MIDDLESEX. TEL: WEST DRAYTON 2288
London: Columbia House, Aldwych, W.C.2 *North*: Albion Ironworks, Manchester 10
Midlands: 83 Edmund St, Birmingham 3 *Scotland*: 169 Hamilton Rd, Glasgow E.2
Paris (Seine): Compagnie Générale de Construction de Fours

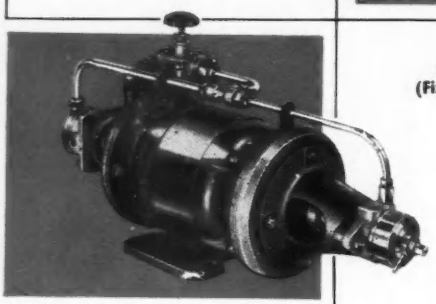
G2



STANDARD UNIT
(Fixed or variable delivery)

MOTORISED UNIT
(Fixed or variable delivery)





SPECIAL UNIT
(Fixed or variable delivery)

This is why Savery Hydraulic Pumps have it all ways

SOME PROVED APPLICATIONS

Hydraulic feeds in machine tools, textile machinery, drilling equipment, test rigs, etc.
Lifting gear in mechanical handling.
Hydraulic equipment in aircraft (80,000 supplied to aircraft industry).
Hydraulic pressure in testing machines.
Metering and mixing equipment.
Pressure lubrication.
Oil burner feed equipment.

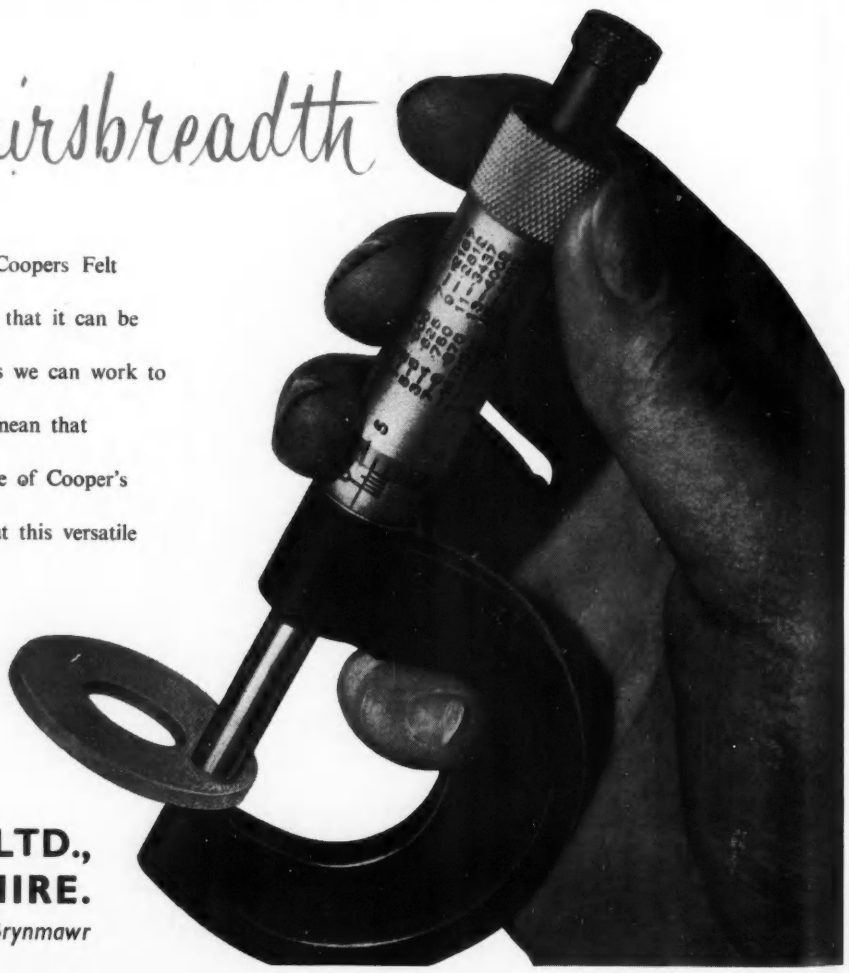
Write for further details to

Thomas Savery Pumps LTD.

BRACEBRIDGE ST · BIRMINGHAM 6 *Tel: ASTON CROSS 1316*

Literally—a hairsbreadth

Today, most progressive engineers think of Coopers Felt as an engineering material, yet many do not know that it can be machined to close limits. With the harder felts we can work to within a hairsbreadth of your specification. Yes, we mean that literally—to the breadth of a human hair. One of Cooper's technical advisers will be happy to tell you more about this versatile material.



COOPERS FELT

COOPER & CO. (B'HAM) LTD.,
BRYNMAWR BRECONSHIRE.
Tel: Brynmawr 312 *Grams: Felting Brynmawr*

THE ENGINEER

VOL. 202 No. 5265 DECEMBER 21, 1956

CONTENTS

LEADING ARTICLES—
Out of Calder Hall... 871
Royal Agricultural Society 872
Clearing the Canal 872

ARTICLES—
Aircraft Materials 885
Central Engineering Establishment of the National Coal Board. (Illus.) 893
Development of Gas-Cooled Reactors for Power Production. (Illus.) ... 881
Engravings of 1881... 886
European Co-operation... 873
Heavy Welding Manipulator. (Illus.)... 897
Institution of Mechanical Engineers ... 873
Machine for Determining Vibration of Precision Ball Bearings. (Illus.) ... 884
Manufacture of a Whale's Head. (Illus.) 896
Mechanical Breathing Machines. No. I. (Illus.) 876
Morgan Brothers (Publishers), Ltd. ... 873
Mr. H. P. T. Lind 885
Myklestad's Method for Non-Uniform Vibrating Beams. No. II. (Illus.) 874
Newsprint Mill at Kemsley. No. II. (Illus.) 888
Powered Lift. (Illus.) 895
Release of Information on Atomic Energy 873
Research on Automobile .Stability. No. III. (Illus.) 879
Rotary Cooler for Granular or Powdered Materials. (Illus.) 897
Underground Gasification of Coal ... 873
300MW Nuclear Power Stations for Great Britain. (Illus.) 891
100 Years Ago... 873

CONTINENTAL SECTION—
International Congress on Rockets and Guided Missiles 899
Individual Axle Drive for Electric Locomotives. (Illus.) 900
Mr. Adolf Brunner... 900
Use of Compressed Air Against Ice ... 900

AMERICAN SECTION—
National Metal Congress and Exposition. No. II. (Illus.) 901

LITERATURE 887

NEWS AND NOTES—
Advanced Engineering Courses 906
British Patent Specifications. (Illus.)... 905
British Standards Institution... 895
Catalogues and Brochures 906
Forthcoming Engagements 906
Industrial and Labour Notes... 898
Launches and Trial Trips 906
Personal and Business 904
Technical Reports 897

SUPPLEMENT—
Tabular Summary of Civil Engineering Contracts, 1956

OUT OF CALDER HALL

Current events in the Middle East provide a melancholy reminder of the inconveniences and dangers to which Great Britain is exposed as a result of depending strongly on conventional fuels. The gloom of the immediate future is, however, lightened to some extent by the bright promise now emerging that nuclear fuel will replace much coal or oil for power generation earlier than could have been conceived possible even twelve months ago. Two announcements made last week help to make this prospect clear. One concerns the award of contracts for three 300MW nuclear power stations (and the progress of negotiations for a fourth station) ; the other, which is, perhaps, equally important as a prerequisite for the rapid development of nuclear power, relates to the agreement between the United Kingdom, the United States of America and Canada for the release of more information on atomic energy.

The contracts for the three nuclear power stations, coming, as they do, within two months of the opening of Calder Hall mark the first logical stage in the development of the gas-cooled, graphite-moderated reactor for power generation on a commercial scale. A comparison between the new contract designs and their progenitor is interesting. The thickness of the pressure vessel has been increased from 2in to 3in. In the Scottish station and the Berkeley station the pressure vessel is to be spherical instead of cylindrical, and in the former a double-shell construction will be adopted to enable appropriate materials to be used for the two distinct functions : a temperature-resistant steel for the inner shell, which is in the hotter zone of the reactor, and a tough, non-brittle steel for the spherical shell which has to withstand the full working pressure of the carbon dioxide gas. The gas temperatures and pressures will be somewhat higher for the new stations than for Calder Hall. More heat will be abstracted by the coolant and more heat exchangers will be required, per reactor, to handle the increased heat output. The steam conditions will be raised to levels suitable for turbo-generators of 60MW capacity, instead of 32MW as at Calder Hall. In brief, while the new stations will be easily recognisable derivatives of Calder Hall, they will, as power producers, represent a notable advance. They will, in fact, be designed for guaranteed outputs of 300MW sent out, which is a spectacular leap ahead of the tentative figure of 100MW to 200MW suggested in the Government's White Paper of February, 1955, announcing Great Britain's nuclear power programme. About the cost of the new stations there is less certainty. Contract information suggests that the capital cost may be between £100 and £130 per kilowatt sent out. Stated slightly more conservatively by the Central Electricity Authority, " the capital cost will be not less than two and a half to three times that of a coal or oil-burning station," and " the nuclear generation cost per unit, initially, will probably be higher than from the Authority's advanced designs of thermal plant." Looking to the future, the Authority hopes and expects that, when more experience has been won on such important matters as the working life of the reactors and the cost and life of the fuel, the capital costs of later nuclear power stations will be progressively reduced and nuclear generation will become competitive with thermal generation and may well become cheaper. That there are solid grounds for these expectations is suggested by the substantial strides that have been made in the short interval between the start of the " Pippa " design study and the completion of Calder Hall " A " station.

But if this state is to be reached quickly a congenial climate is required for the rapid spread of ideas and applied knowledge in nuclear engineering, and we, therefore, welcome the announcement that the United Kingdom, the U.S.A. and Canada have agreed upon " a comprehensive extension of the information on atomic energy which may be freed from security restrictions." Information about present-day and future reactor systems, and about some details of the design and operation of chemical plants for recycling spent fuel, and many other subjects, is to be " declassified." This relaxation of security, which we have long advocated, comes not a moment too soon. The progress envisaged by the C.E.A. depends upon the widespread dissemination of knowledge which has hitherto been con-

confined to a few small groups of scientists and technologists. With the brakes off, industry will be able to advance more freely.

THE ROYAL AGRICULTURAL SOCIETY

The Royal Agricultural Society of England is among the oldest of our scientific institutions. Since its formation, 118 years ago, it has striven continuously, in all kinds of ways, to assist the improvement of British agriculture. The Society has, in accordance with the declared aims of its founders, regularly taken "measures for the improvement of the education of those who depend upon the cultivation of the soil for their support," and it has been busy encouraging "men of science in their attention to the improvement of agricultural implements." Throughout all the years of its distinguished existence, in fact, the Royal Agricultural Society has faithfully endeavoured to live up to its motto "Practice with Science." In so doing, the work of engineers has had a prominent place, and in the Society's activities engineers have at all times played an important part. That is not surprising, for, as was remarked in these columns as long as a century ago, "the talents of the engineer can be applied as profitably to the land as the road, to the plough as to the locomotive, and there is not one of us, be he whom he may, who has not, directly or indirectly, a stake in the soil, and an individual interest in its culture and improvement."

One of the ways in which engineers have participated in the Royal Agricultural Society's work is concerned with competitive machinery trials which, in earlier times, were organised annually. There is no doubt that these trials helped, in a practical manner, the development and improvement of agricultural machinery. In more recent years this aspect of the Society's work has been less prominent, though since the war there have been trials of machines for collecting forage crops and for the complete harvesting of potatoes. At present, there is in progress a competition for ditch cleaning machines, the performance trials of which will unquestionably produce some useful results. By far the best-known part of the Royal Agricultural Society's work, however, is its staging of the Royal Show, an event which has taken place virtually every year since 1839, apart from breaks caused by the exigencies of the two world wars. The Royal Show, a summer season function, is probably still the largest show of its kind in the world. It was started as the Society's "country meeting," at which there were some exhibits of livestock and newly-invented or improved implements, and an important part of which was a conference for the reading and discussion of prize essays. Traditionally, since 1839, the Royal Show has had no fixed abode; every year it is held in a different part of the country, which gives it a certain amount of local colour; but always it has drawn large numbers of visitors from all over this country and from many countries overseas. By some, the Royal Show has been described as a gigantic country fair and by others as a pageant of British agriculture. In general, however, full acknowledgment of its educational value would be readily accorded. Furthermore, we feel that many would opine that the consistent support of the agricultural engineering firms which the Society has for so long enjoyed has enabled the Royal Show to be organised year by year. In whatever terms the Royal Show may be described, it can be fairly claimed that it has done much to stimulate the fuller mechanisation of the world's agriculture.

Last week, the Royal Agricultural Society held its annual general meeting. There, it was suggested that many of the activities—such as research, experimental and advisory work—which the Society had been accustomed to initiate in the past had now become the responsibility of Government and other organisations. It was also suggested that "the outstanding responsibility left to the Society is the presentation of all that is best in British agriculture at a show which is without rival in the world." At the present time, the machinery, implements and other equipment designed and produced by engineers form by far the greater part of "all that is best in British agriculture," and therein is presented a problem to which the Council of the Society is compelled to give earnest consideration. To maintain the "migratory" character of the Royal Show means that ever-increasing costs have to be faced by the organisers; items like site preparation, road making, and the transport and erection of pavilions and shedding involve a formidable annual account. The costs which have to be borne by exhibitors are just as heavy, and there have been a few criticisms that the game may not always be worth the candle! For the past year, a sub-committee of the Royal Agricultural Society's council has been examining questions related to future show policy, and in an interim report it has hinted that the Society may be obliged to consider obtaining a permanent ground for its annual show. We confess to regret as we contemplate the possibility that before long the Royal Show may lose its traditionally vagrant character. Part of the show's educational value is to be derived from those local engineering characteristics and diverse crafts that may still be discovered in different regions of the country. Yet we realise, as engineers, that what has become traditional may not always measure up to the need of the present. If the Royal Agricultural Society is to continue to meet effectively the challenge of its motto "Practice with Science," it will no doubt determine that it is beneficial to organise its affairs in a way that will serve the best interests of the agricultural engineering industry. For that industry is of paramount importance in the business fo world food production.

CLEARING THE CANAL

In a statement in Parliament on Monday, Mr. Selwyn Lloyd revealed, what many had already suspected, that arrangements for clearing the Suez Canal are not going well. Presumably his estimate that if all the Anglo-French resources on the spot were used a channel could be cleared in seven weeks is based not upon an exact survey, but on such knowledge as is in our hands from air photography; nor did he state whether the channel so cleared would permit the passage of the larger vessels accustomed to using the canal. But he was undoubtedly right in stressing that in the interest of many countries in Europe and in Asia the matter should be treated as one of emergency. In fact, however, it is abundantly obvious that the Egyptians are making objections to the use of the Anglo-French fleet of salvage vessels; and their repugnance to having the work done by British and French forces must be recognised even if it may be suspected that one of their objects is to inflict a humiliation on Britain and France. Yet it is difficult to believe that the Egyptians, who, even though in lesser degree than other nations, are still losers by the blockage of the canal, really desire to delay its reopening. Has the point, we wonder, been firmly put to the Egyptians by the United Nations that there is no escape from the conclusion that to clear the canal speedily the salvage ships on the spot and their experienced crews must necessarily be employed? It is nonsensical to suppose that there would not be lengthy delay in getting together a similar fleet of salvage vessels from "neutral" nations; and even more nonsensical to suppose that "scratch" crews manning the vessels now on the spot could carry out the work quickly. These sound to us like the suggestions of people lacking knowledge of the technical and operational problems involved in salvage works. There is, of course, a further difficulty. The safety of crews and of equipment, as Mr. Selwyn Lloyd rightly stressed, must be guaranteed before they could be handed over to the care of the United Nations. There, possibly, lies the crux of the matter. Such a guarantee would necessarily involve the maintenance on Egyptian soil of a United Nations force until such time as the canal was cleared; and, no doubt, also, during the period of negotiations about the future of the canal. That situation might well affect the issue of the negotiations. Is that an argument which the United Nations should support?

A Seven Day Journal

Morgan Brothers (Publishers), Ltd.

MR. C. A. VIAN has been appointed chairman of Morgan Brothers (Publishers), Ltd., proprietors of THE ENGINEER. He succeeds the late Sir Austin Hudson, Bt., whose death was recorded in our issue of December 7. Mr. Vian, who joined the company in 1925, was appointed a joint managing director in 1945. He became managing director in 1949, and retains that office in addition to the chairmanship.

Institution of Mechanical Engineers

AT a general meeting of the Institution of Mechanical Engineers last Friday evening, a portrait, by Holman Hunt, of the first Sir William Fairbairn was unveiled by his great-grandson, Sir William Fairbairn, by whom it has been presented. The president of the Institution, Mr. T. A. Crowe, said that the Institution was both proud and pleased to add the portrait to many other valued possessions associated with a long line of distinguished past-presidents. Lord Dudley Gordon, in a citation on the first Sir William Fairbairn, recalled that he was the Institution's third president. He was one of the men, Lord Dudley said, who could be regarded as founders of the modern profession of mechanical engineering in succession to millwrighting. Lord Dudley also spoke about Fairbairn's friendship with George Stephenson and recalled Fairbairn's shipbuilding and locomotive building activities. In all, he said, Fairbairn turned out about 600 locomotives and was the inventor of the tank engine. Then, too, the citation continued, Fairbairn presented a paper on "The Prevention of Smoke" at the British Association's meeting at York in 1844. In the following year, Robert Stephenson conceived the idea of a tubular bridge to carry railway trains and consulted Fairbairn, who made experiments at his Millwall works. The two men were mainly responsible for the Menai tubular bridge, and by 1870, Fairbairn had designed and built nearly 1000 bridges, some with spans of up to 300ft. In addition, Fairbairn was credited with being the inventor of the Lancashire boiler, for which he took out a patent in 1844. The first Sir William Fairbairn died in 1874 at the age of eighty-five, about which event, Lord Dudley Gordon said, THE ENGINEER commented: "No man has done so much to make mechanical engineering in two important branches so nearly perfect. He abolished the millwright and introduced the mechanical engineer."

European Co-operation

THE principal guest at the annual luncheon of the British Engineers Association, which was held in London last week, was Jonkheer H. F. L. K. van Vredenburch, chief representative in the United Kingdom of the High Authority of the European Coal and Steel Community. In an after-luncheon address he spoke about trends in European co-operation, the interest in which in this country he described as "quite remarkable." In a reference to the proposals for a common European market, Mr. van Vredenburch said that there must, of course, be safeguards for labour, for resettlement, and for technical retraining if workers were compelled to seek new jobs. To that end, the six nations concerned intended to create a "readaptation fund." There must also be safeguards for industry, he added, and consequently an investment fund would be established which would provide funds for industrial reconversion by individual firms. Commenting on the British plan of association with the common European market, Mr. van Vredenburch said that it was the most encouraging and constructive step towards closer European co-operation which this country had taken in the past twenty-five years. But, Mr. van Vredenburch observed, these schemes were no substitute for the spirit of enterprise, for ingenuity, and not even for sheer hard work! If the schemes were, in due time, put into effect, Europe would still remain a number of nations and not one federal state such as the U.S.A. Therefore, the present plans did not mean that the end of the road leading to European unity would have been reached. But, Mr. van Vredenburch emphasised, the fulfilment of the plans did mean the foundation upon which European unity might one day rest. Without a solid, common economic basis, there could never be success.

The Engineer
100 Years Ago
(DECEMBER 19, 1856)

"ALUMINIUM FOR COINAGE"

"We some time ago, and more than once, heard it suggested that use should be made of the newly discovered metal, aluminium, for the purpose of national coinage, but we never supposed the suggestion was made seriously; yet it would appear from the prominence given to the subject by one of our morning contemporaries, that the notion has been really entertained, and more generally than we conceived it possible. We should be very loth to believe that any step will be taken in this direction, notwithstanding the great and rapidly increasing scarcity of gold and silver, for aluminium, though very pretty to look at, is not at all a metal suited for coin. It is true it is at the present moment possessed of considerable intrinsic value, because it is scarce in supply, but the raw material is plentiful, almost as the sands of the ocean, and to say nothing of its lightness of weight, which alone is sufficient to condemn it, there is no possibility of limiting its production, or of, in fact, ascertaining even the remotest approximation to a standard of value. Let the demand be increased, and the supply will be found quickly at hand.

"We have heard, too, a wicked suggestion that Mr. Bessemer's very completely purified iron, such as was exhibited at Cheltenham, and of which we have a dazzling silvery specimen before us, should be used as currency; but we have never heard this suggestion echoed, though less likely things have come to pass ere this. If, however, we are compelled to resort to a new currency medium we should prefer the adoption of nickel, of which use could be advantageously made in relief of the silver currency. Nickel is a cleanly metal, is of nearly the same specific gravity as silver, and will work kindly in the mass; At the same time it is of limited production, and, as a *dernier ressort*, would be infinitely less objectionable than aluminium. We confess, however, we should be very sorry to see the introduction of any outsiders into our currency, and we think great difficulty would be found in persuading the masses to believe that any thing short of gold or silver would be worth the hoarding. Fancy, a stocking, full of aluminium!"

Release of Information on Atomic Energy

AN agreement has been reached between the United Kingdom, the U.S.A. and Canada for a comprehensive extension of the information on atomic energy which may be freed from security restrictions. The U.K. Atomic Energy Authority states that representatives of the atomic energy organisations of the three countries meet periodically to discuss the security classification of information in fields of common interest and that the declassification guide to which all three bodies work has now been amended. As a result of this change, it is stated that a considerable volume of material will become available to assist the peaceful development of atomic energy as reports, drawings and other material are reviewed and declassified. British industrial organisations engaged on the nation's nuclear power programme should find the new classes of information particularly valuable. For example, although many of the details of the Calder Hall reactor have been published, some aspects could be obtained only under certain security restrictions involving limitations on those engaged in the work. Acquisition of information not only of this kind but about reactors under consideration for the future is now freed from security restrictions. Aspects of nuclear power covered by the declassification guide include ore recovery and fabrication of fuel elements and the design and operation of plants for chemical recycling of spent fuel from civilian power reactors. It will now be possible to release for the first time detailed production figures of uranium ores and concentrates. The results of this new agreement will be seen in reports and papers which will be published or delivered in the form of lectures in due course, in relaxed conditions for negotiating bilateral agreements, and in the declassification of many earlier reports hitherto not available for general publication.

Underground Gasification of Coal

THE National Coal Board has appointed Sir Alexander Gibb and Partners, in association with Messrs. Cremer and Brearley, to act as consultants in carrying out its development of underground gasification, for which the firm of Humphreys and Glasgow, Ltd., will be the main contractor for the engineering and scientific work. It is planned that a pilot scheme shall be in operation by the end of 1958 and under it gas will be delivered to a 5MW generating plant to be built by the Central Electricity Authority. The site chosen for this pilot scheme is that at Newman Spinney, near Barlborough, on the borders of Yorkshire and Derbyshire. The coal seam chosen for gasification is of secondary quality and is not worth mining because of its high ash content. In making this announcement the Coal Board points out that some 5000 tons of coal have already been gasified in a series of experiments it has carried out in conjunction with the Ministry of Fuel and Power. Abstracts from a report on these trials were given in THE ENGINEER of April 13 and 20 last. In the pilot scheme there will be used the most promising techniques in which horizontal bore-holes in the coal carry both the gas and the air needed for gasification. In one of these techniques holes are bored in the coal connecting two galleries; in another the holes are blind and they contain a pipe that conveys air and steam to the reaction zone, whilst the gas returns outside the pipe. As work on the pilot scheme progresses a full-sized power station will be planned.

Myklestad's Method for Non-Uniform Vibrating Beams

By R. E. D. BISHOP*

No. II—(*Concluded from page 840, December 14*)

The Myklestad method of tabular calculation is an extension of Holzer's well-known method for torsional vibration to the flexural motion of beams. It is a powerful method of vibration analysis and is shown here to be, essentially, a means of calculating the receptances of beams. The tables are presented in a form which is thought to be simpler to use than previous versions. A simple experimental check of the calculations that are used in describing this method confirmed their accuracy.

The Calculation of Receptances from the Tables

WHEN a table such as Table I *ante* is completed it gives the amplitudes of deflection v, slope θ, shearing force s and bending moment b along the span and the necessary force and couple which must be applied at the left-hand end to produce them. This information is given in terms of two amplitudes which refer to the right-hand end and is obtained for the particular excitation frequency for which the table is constructed. It is now a simple matter to find any of the receptances α_{x0}, $\alpha_{x'0}$, $\alpha_{x0'}$, or $\alpha_{x'0'}$ for the beam where $0 \leqslant x \leqslant l$. As a consequence of the reciprocal property of receptances it follows that α_{0x}, $\alpha_{0x'}$, $\alpha_{0'x}$ and $\alpha_{0'x'}$ can also be found. For while reversal of the order of the subscripts of a receptance alters its meaning, it does not change its value.

To illustrate the method of calculation the receptance $\alpha_{0'0'}$ of the beam shown in Fig. 4(*a*) will be found (for $\omega = 1000$ rad./sec.) under the assumption that it is simply supported at its left-hand end.

It is seen in Table I that the requirement of zero deflection at the section $x=0$ demands that

$$2{\cdot}126V_1 - 1{\cdot}244\Theta_1 = 0 \quad . \quad . \quad . \quad (22)$$

or

$$\Theta_1 = 1{\cdot}709V_1 \quad . \quad . \quad . \quad . \quad (23)$$

The amplitudes of both the slope and the bending couple at particle 7 (i.e. at $x=0$) can now be written down as functions of V_1 only.

Thus

$$\Theta_7 = (-5{\cdot}497 + 2{\cdot}500 \times 1{\cdot}709)V_1 = -1{\cdot}225V_1 \text{ rad.} \quad . \quad (24)$$

$$M_7 = (-0{\cdot}4136 + 0{\cdot}1377 \times 1{\cdot}709) \times 10^6 V_1 = -0{\cdot}1783 \times 10^6 V_1 \text{ pdl. ft} \quad . \quad (25)$$

The required receptance is therefore

$$\alpha_{0'0'} = \frac{\Theta_7}{M_7} = 0{\cdot}6870 \times 10^{-6} \text{ rad./pdl. ft.} \quad (26)$$

Notation.

b—Bending moment.
E—Young's modulus.
I—Second moment of area about flexural axis.
l—Length of beam.
M—Amplitude of bending moment.
m—Mass of particle.
n—Number of particles used in representation of beam.
q—Generalised co-ordinate.
r—Subscript used to denote the rth particle or the rth segment of beam.
S—Amplitude of shearing force.
s—Shearing force.
V—Amplitude of deflection.
v—Deflection.
x—Distance along beam (see Fig. 3(*a*)).
α—Receptance of beam using the following convention:
α_{xb}' = amplitude of v at section x due to couple of unit amplitude applied in positive direction of θ at section $x=h$.
$\alpha_{a'b'}$ = amplitude of θ at section x due to this couple.
α_{xa} = amplitude of v at section x due to force of unit amplitude acting in positive direction of v at section x.
$\alpha_{a'a}$ = amplitude of θ at section x due to this force.
ξ, η, ζ—Elastic constants defined as in Fig. 2.
Θ—Amplitude of slope, θ.
θ—Slope ($= \partial v/\partial x$).
ρ—Mass density.
ω—Frequency of excitation (rad/sec).

* University Lecturer in Engineering and Fellow of Pembroke College, Cambridge.

The amplitude of the slope or deflection at any of the seven particles can be found in the manner of equation (24). For instance, the deflection of particle 4 is

$$V_4 = (1{\cdot}073 - 0{\cdot}5046 \times 1{\cdot}709)V_1 = 0{\cdot}2106V_1 \text{ ft} \quad . \quad . \quad . \quad . \quad (27)$$

That is to say

$$\alpha_{(l/2)0'} = \frac{V_4}{M_7} = -1{\cdot}181 \times 10^{-6} \text{ ft/pdl. ft} \quad . \quad (28)$$

The curve shown in Fig. 6 has been found in this way, being that of $\alpha_{x0'}$, plotted against

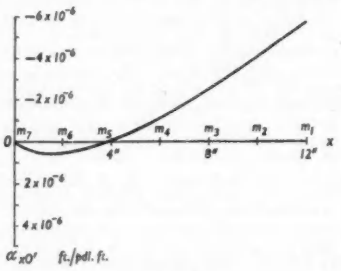


Fig. 6

x for the beam of Fig. 4, assuming the end $x=0$ to be pinned.

As a third example, the cross receptance α_{l0} will be calculated from Table I for the given beam under the assumption that the end $x=0$ is free and, of course, that $\omega = 1000$ rad./sec. No couple is to be applied at the left-hand end so that

$$M_7 = (-0{\cdot}4136V_1 + 0{\cdot}1377\Theta_1) \times 10^6 = 0 \quad . \quad (29)$$

From this it follows that

$$\Theta_1 = 3{\cdot}004V_1 \quad . \quad . \quad . \quad . \quad (30)$$

While the amplitude of deflection at particle 1 is simply V_1, that of the shearing force at particle 7 is

$$S_7 = (-0{\cdot}9290 + 0{\cdot}4134 \times 3{\cdot}004) \times 10^6 V_1 = 0{\cdot}3129 \times 10^6 V_1 \text{ pdl.} \quad . \quad (31)$$

Thus the required receptance, which is given by their ratio, is

$$\alpha_{l0} = \frac{V_1}{S_7} = 3{\cdot}196 \times 10^{-6} \text{ ft/pdl.} \quad . \quad . \quad (32)$$

The direct receptance $\alpha_{0'0'}$ of equation (26) was evaluated for a driving frequency $\omega = 1000$ rad./sec. A series of such calculations has been made for various values of ω and the receptance—or, rather, its reciprocal—is plotted against frequency in Fig. 7. The reason for plotting $1/\alpha_{0'0'}$ instead of the quantity $\alpha_{0'0'}$ is that, for some purposes, the former curve is the more useful. The curve has a characteristic shape which is common to the reciprocals of all direct receptances of all engineering systems in the absence of their damping as is explained by Johnson.[5] This interesting fact is used by that writer to demonstrate, in a simple fashion, certain general properties of vibrating structures.

The horizontal asymptotes of this curve occur at the "anti-resonance frequencies" of the pinned-free beam, since, at the corresponding values of ω, $\alpha_{0'0'}$ is zero. These are the natural frequencies of the clamped-free bar and the two lowest values are 610 and 4180 rad./sec. Where the curve intersects the frequency axis, the receptance is infinite.

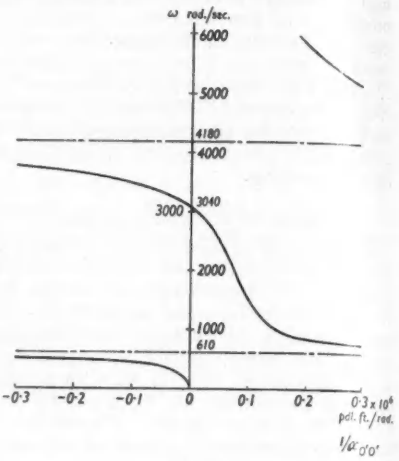


Fig. 7

These frequencies, of which the lowest is 3040 rad./sec, are the natural frequencies of the pinned-free beam.

It would, of course, be more accurate to refer to the above sets of frequencies as the anti-resonance frequencies and the natural frequencies of the idealised beam of Fig. 4(*b*). They represent approximations to those of the original beam of Fig. 4(*a*). The accuracy of these approximations diminishes with increasing ω for the given number of particles.

It is of interest to examine the effects upon these results of increasing the number of particles used in representing the beam of Fig. 4(*a*). If this number is increased from 7 to 13 equally spaced particles then the first two intersections referred to in Fig. 7 are found to occur at $\omega = 610$ and 3050 rad./sec. Thus increasing the number of particles does not appreciably improve the accuracy in this range of frequency. Four significant figures were used in all calculations.

If a table is constructed for either a natural frequency or an anti-resonance frequency of the beam, then the appropriate principal mode may be found. This is given by the relative magnitudes of the amplitudes of deflection in column 3. It was found, for instance, that $\omega = 610$ rad./sec is the first anti-resonance frequency of the bar of Fig. 4 when its left-hand end is pinned (see Fig. 7). A table was constructed for this frequency using a 13-particle representation and V_{13} was equated to zero so that a result of the form (23) was obtained. This permitted all the amplitudes of deflection

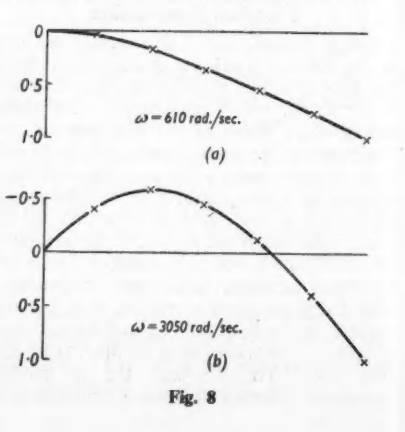


Fig. 8

V_2, V_3, ... to be expressed in terms of V_1 and, incidentally, led to the result $\Theta_{13}=0$ (signifying an anti-resonant state of the pinned-free beam or a resonant state of the clamped-free beam); in this way the shape of the modal curve, shown in Fig. 8(*a*), was found.

In a similar way, the curve of Fig. 8(*b*) was found, using the first resonance frequency of $\alpha_{6'0'}(\omega=3050$ rad./sec). This is the first principal mode that the beam of Fig. 4 possesses when its left-hand end is pinned. Higher modes than the first may be found by the use of this technique.

It is of interest to check the accuracy of the 7-particle representation in the calculations of principal modes. The appropriate results, corresponding to $\omega=610$ and 3040 rad./sec, respectively, are marked with crosses on the curves of Fig. 8(*a*) and 8(*b*).

Continuous and Overhung Beams

Once the receptances have been found for a beam, they can be used in all the ways that are mentioned in an earlier paper.[7] They are the necessary data for the beam that is required in analysing free or forced oscillation of any system which contains the beam. In particular a vibration analysis may be made of a continuous—or of an overhung—beam if the receptances of its various spans are known.

Consider, for instance, the (non-uniform) beam *A* shown in Fig. 9(*a*). Suppose that the direct receptance at the slope q_1 of the left-hand end were required. This can be found from the receptances β_{11}, β_{12} and β_{22} of the left-hand beam alone, together with γ_{22} of the right-hand span alone where q_2 is the slope at the right-hand support.§ In fact, it can be shown simply by imposing conditions of equilibrium and compatibility on the separate portions *B* and *C* that the required receptance is[6]

$$\alpha_{11}=\beta_{11}-\frac{\beta^2_{12}}{\beta_{22}+\gamma_{22}} \quad . \quad . \quad . \quad (33)$$

Now if the separate spans *B* and *C* of Fig. 9(*b*) are non-uniform, this formula can be used once the tables have been constructed for each. This is unnecessarily troublesome,

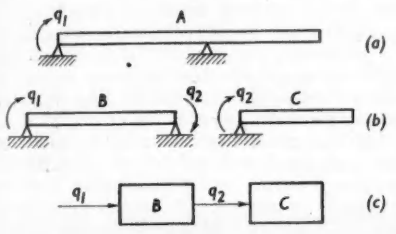


Fig. 9

however, as the beam *A* can be treated by the tabular method as a single unit. Starting at the right-hand end, the method proceeds in the usual way until the right-hand support is reached, the unknown amplitudes being V_1 and Θ_1.

At this point the conditions of equilibrium and compatibility can be imposed and the calculation continued across span *B*.

This may be illustrated with Table I. Suppose that the span *C* (Fig. 9(*b*)) is the same as the beam of Fig. 4(*a*) and that the receptance α_{11} of the system of Fig. 9(*a*) is required for $\omega=1000$ rad./sec. Table I shows the first part of the calculation. The fact that m_7 should be augmented somewhat by the contribution of the mass of the first section of span *B* is of no consequence since its deflection is to be made zero. At particle 7, the deflection is zero so that

$$2\cdot126V_1-1\cdot244\Theta_1=0 \quad . \quad . \quad . \quad (34)$$

or

$$V_1=0\cdot5851\Theta_1 \quad . \quad . \quad . \quad . \quad (35)$$

The table for beam *B* can now be commenced starting (in column 1) at mass 7. At this mass the first entry in column 3 is

$$V_7=0\times\Theta_1+0\times S_7 \quad . \quad . \quad . \quad (36)$$

and the first entry in column 5 is

$$S_7=0\times\Theta_1+1\times S_7 \quad . \quad . \quad . \quad (37)$$

since the amplitudes Θ_1 and S_7 must now be carried through this table instead of V_1 and Θ_1. The condition of equilibrium at the

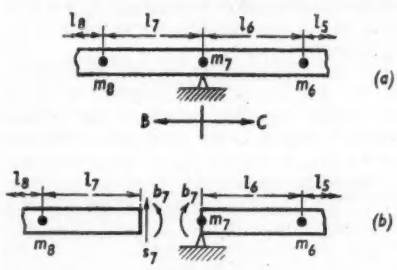


Fig. 10

junction determines the first entry in column 6; from Table I it is found to be

$$M_7=(-0\cdot4136V_1+0\cdot1377\Theta_1)\times10^6 \quad . \quad (38)$$

which for the purpose of the next table may be written as

$$M_7=(-0\cdot1043\Theta_1+0\times S_7)\times10^6 \quad . \quad . \quad (39)$$

in virtue of equation (35). Finally, compatibility of the two spans at their junction requires that the first entry in column 7 of the table for span *B* shall be

$$\Theta_7=-5\cdot497V_1+2\cdot500\Theta_1$$
$$=-0\cdot7163\Theta_1+0\times S_7 \quad . \quad . \quad . \quad (40)$$

The calculation for this second table can now proceed in the usual way.

Experimental Check of Results

Having performed the calculations outlined in this article, the writer decided to make a simple experimental check of the two anti-resonance frequencies for rotation at a pinned end of the bar shown in Fig. 4(*a*) A bar was turned having the dimensions shown, but with a substantial extension whose diameter was about an inch. This extension was clamped as firmly as possible on a concrete base, so that the portion of the test piece which is shown in Fig. 4(*a*) could be made to vibrate as a cantilever. Excitation was provided by a small electro-magnet placed near the free end of the bar and lateral motion was detected by means of a capacitance pick-up. The electric circuit which was used was of a conventional type and resonances were detected by Lissajou figures on a cathode-ray oscilloscope.

The first and second resonant frequencies of the test piece were found to be

$$95 \text{ c/s and } 663 \text{ c/s} \quad . \quad . \quad . \quad . \quad (41)$$

The predictions of the theory, on the other hand, were (for the seven-particle representation of Fig. 4(*b*)) :—

$$\left.\begin{matrix}610 \text{ rad./sec or } 97 \text{ c/s}\\ 4180 \text{ rad./sec or } 665 \text{ c/s}\end{matrix}\right\} \quad . \quad . \quad (42)$$

This experimental check thus provided confirmation of the accuracy of the calculations. The discrepancies between the two sets of results can easily be accounted for by experimental errors. To some extent, the agreement must be regarded as fortuitous, since the values of *E* and ρ which were used in the calculations (see equation (17)) were simply the usually accepted values‖; they were not checked by test.

Conclusions

In two recent papers before the Institution of Mechanical Engineers,[7,8] a general method is developed of dealing with the vibration of beams. By using the elementary concept of receptance in a systematic fashion, it has been shown how an enormous range of systems can be analysed using only fundamental considerations of mechanics. Numerical tables of receptances have been presented,[7, 12] for uniform beams and the analytical technique has been explained both in general terms and with special reference to frames.[8] There remains one problem, namely, that of calculating the receptances of non-uniform beams.

In this article, Myklestad's method has been adapted to satisfy this need. The numerical method which is due to that author is a very powerful one and, as far as the writer is aware, it has been published only in the forms that Myklestad and Prohl devised. It may be remarked, parenthetically, that Myklestad achieved some simplification of his original method of attack as is explained in reference [1]. These considerations have led the writer to re-derive the theory and, as a result of some experimentation, to alter the form and content of the tables with a view to making them easier to understand. It is the writer's belief that arithmetical methods such as Myklestad's are, as a class, generally the most desirable for practical use in industry.

References

[1] Myklestad, N. O., "A New Method of Calculating Natural Modes of Uncoupled Bending Vibration of Airplane Wings and Other Types of Beams," *Journal of the Aeronautical Sciences*, Vol. 11, No. 2, pages 153–162, April 1944.
[2] Myklestad, N. O., *Vibration Analysis*, McGraw-Hill, London, 1944.
[3] Prohl, M. A., "A General Method for Calculating Critical Speeds of Flexible Rotors," *Journal of Applied Mechanics*, Vol. 12, No. 3, pages 142–148, September, 1945.
[4] Duncan, W. J., "Mechanical Admittances and their Applications to Oscillation Problems," R. and M. 2000, 1947.
[5] Johnson, D. C., "The Application of Admittance Methods in the Classical Theory of Small Oscillations," *Engineering*, Vol. 171, No. 4453, pages 650–652, 1951.
[6] Bishop, R. E. D., "The Analysis and Synthesis of Vibrating Systems," *Journal Roy. Aero. Soc.*, Vol. 58, pages 703–719, October, 1954.
[7] Bishop, R. E. D., "The Analysis of Vibrating Systems Which Embody Beams in Flexure," *Proc. Inst. Mech. Eng.*, Vol. 169, No. 51, 1955.
[8] Bishop, R. E. D., "The Vibration of Frames," *Proc. Inst. Mech. Eng.*, Vol. 170, No. 29.
[9] Den Hartog, J. P., *Mechanical Vibrations*, Ed. 3, McGraw-Hill, London, 1947, page 238.
[10] Duncan, W. J., "A Critical Examination of the Representation of Massive and Elastic Bodies by Systems of Rigid Masses Elastically Connected," *Quarterly Journal of Mechanics and Applied Mathematics*, Vol. 5, Part 1, pages 97–108, 1952.
[11] Livesley, R. K., "The Equivalence of Continuous and Discrete Mass Distributions in Certain Vibration Problems," *Quarterly Journal of Mechanics and Applied Mathematics*, Vol. 8, Part 3, pages 353–360, September, 1955.
[12] Bishop, R. E. D., and Johnson, D. C., *Vibration Analysis Tables*, Cambridge University Press, 1956.

§ These receptances are, in the previous notation used in this article,

$\beta_{11}=\alpha_{6'6'}$; $\beta_{22}=\alpha_{1'1'}$; $\beta_{12}=\alpha_{6'1'}$ for the pinned-pinned beam *B* and

$\gamma_{22}=\alpha_{6'6'}$ for the pinned-free beam *C*.

‖ The value quoted for *E* is given by $(30\times10^6)\times144\times32$ pdl./ft^2.

North East Coast Institution of Engineers and Shipbuilders.—On Friday, December 14, Kaare Haug, B.Sc., and Norman Carter presented their paper "M.S. 'Bergensfjord,'" before the North East Coast Institution of Engineers and Shipbuilders. The paper gives the main dimensions and a general description of the ship, including tables giving results of model experiments, notes upon the structure of the main hull, with particular reference to the problems related to the aluminium alloy superstructure. Some account is given of the ventilation systems and the scheme for fire protection, and there is a brief survey of the main details of main and auxiliary machinery. The paper includes profile and deck plans, a lines plan, sectional drawings and details of construction, together with a general arrangement of the machinery spaces.

Mechanical Breathing Machines

By CAPTAIN G. T. SMITH-CLARKE

No. I

Epidemics each summer of poliomyelitis have caused the hospitals in this country to become worried about the quality and quantity of breathing equipment available in this country. The author of this James Clayton Lecture presented before the Institution of Mechanical Engineers last Friday, December 14, is chairman of the Coventry, Nuneaton and Rugby Group Hospital Management Committee and has been personally responsible for designing much of the apparatus now in use described in the lecture.

IN April 1952, the Senior Administrative Medical Officer of the Birmingham Regional Hospital Board became very worried about the quality and quantity of breathing equipment available in his region in the event of a large-scale epidemic of poliomyelitis. A medical committee was set up to study the question of mechanical breathing equipment, and I was asked to sit on the committee as honorary consulting engineer. Investigation showed that in the whole of the British Isles, including the Services, so far as could be ascertained, some forty Bragg-Paul pulsators, thirty Drinker breathing machines, and about 700 Both breathing machines, of the type manufactured and generously donated to hospitals by Lord Nuffield, in 1939, remained in service. The Both breathing machine, which popularly but quite erroneously, came to be known as the Nuffield iron lung, was of very simple construction and left much to be desired as to design, durability, and comfort for the patient. However, despite these criticisms, it has given invaluable service and there is no doubt that but for Lord Nuffield's remarkable foresight, Britain would have been in a disastrous position, as to the provision of breathing machines.

At the time of this investigation (1952) the attitude of the Ministry of Health to the question appeared to be :

(1) The cost of providing the minimum number of new breathing machines adequately to cover the British Isles would probably exceed £1,000,000 at post-war prices and, in the financial state of the country it was very doubtful, whether such a large amount could be provided, and,

(2) Even if funds could be provided there were no modern breathing machines in production in Britain, and, most certainly, foreign currency could not be made available for their purchase.

In view of this position, a committee had been considering for a long time the possibility of carrying out some modernising of the Nuffield Both machine but nothing very practical had resulted.

At this time the Birmingham Regional Hospital Board had available to cover its very extensive region, six Bragg-Paul, two Drinker, and forty-eight Nuffield Both machines. The Birmingham committee gave very careful consideration to the matter and decided that, to permit immediate action, the only possible course was to undertake such modifications to the Nuffield Both machines as would make them reasonably serviceable, if only for a comparatively short time. These machines were already thirteen years old and in some cases were in very bad condition owing to unavoidable neglect and exposure during the war years. This was the position when I commenced the work I am about to describe.

The Mechanics of Respiration

To understand the action of mechanical breathing machines and to appreciate the reasons for the several different types which I shall describe, it is necessary to know something of the mechanics of respiration.

Only a medical man, with specialised knowledge and long experience, could explain adequately the intricate and complicated mechanism which functions as the human respiratory system, and undoubtedly a whole series of lectures would be required to cover the subject.

Fortunately, however, it will be sufficient for the purpose of this lecture if I give a very much simplified outline of the system, concentrating upon the three primary factors which affect the design and action of mechanical breathing machines :

(1) All living things, excluding some micro-organisms, must be supplied with oxygen. The oxygen is absorbed by the blood in the lungs and is carried to the tissue cells wherein carbon is oxidized to carbon dioxide and hydrogen to water, the carbon dioxide being carried by the blood back to the lungs and passed out to the atmosphere during expiration. In normal health the oxygen is obtained from the atmospheric air we breathe. The average adult pair of lungs contains approximately 5 litres of air and of this about 500 cubic centimetres is expired and replaced by fresh atmospheric air once per complete breathing cycle. At the average breathing rate of sixteen per minute, the amount of air change will be in the order of 8 litres per minute.

(2) The lungs are situated in a closed compartment, known as the thoracic cavity (the chest). They commmunicate with the atmosphere by way of the trachea (windpipe), the pharynx (throat), and the nasal openings. The flow of air into and from the lungs depends entirely upon changes in the capacity of the thoracic cavity, the lungs do not expand and contract of themselves but only in relation to changes of air pressure in the thoracic cavity, caused by the changes in its capacity. During the normal inspiration period the thoracic cavity is enlarged in all dimensions, but mainly in the transverse and vertical directions. The increase in the transverse direction is brought about by muscular action upon the ribs and sternum (breastbone). The enlargement in the vertical direction is due to downward pull of the large muscle, known as the diaphragm, which divides the thoracic cavity from the abdomen; thus the walls of the thoracic cavity and the diaphragm act together as a bellows-type air pump. For reasons which I must ask you to accept without further explanation, the pressure in the thoracic cavity, that is, between its wall and the lungs, is and must always be subatmospheric, and in health the lungs are expanded against their natural elasticity by atmospheric pressure. Thus as the capacity of the thoracic cavity is increased by expansion, atmospheric pressure causes more air to pass into the lungs and they are expanded to maintain contact with the thoracic walls. During the expiration period the thoracic cavity resumes its normal dimensions, and the decrease in its volumetric capacity, together with the elastic recoil of the lungs, causes the excess air to pass out through the nasal openings at zero or only slight positive pressure. It will be clear that the human respiratory system is a negative pressure system, in which the mean pressure is subatmospheric.

(3) The foregoing explains the pumping system which ensures the air changes required for the reconditioning of the blood, but this is complicated by the fact that situated inside the air pump is a second very complicated pump (the heart), and part of its piping system (the arteries and veins). This pump is responsible for the circulation of the reconditioned blood by way of the arteries to the tissue cells and for the return of the used blood by way of the veins to the lungs for reconditioning. This second pumping system is conditioned to work normally in the mean subatmospheric pressure found in the thoracic cavity. If this pressure is appreciably altered for any considerable time, there may be serious repercussions on the heart action.

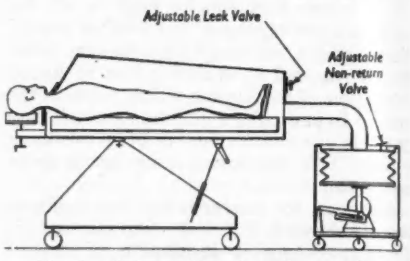


Fig. 1—Modern cabinet breathing machine

A further complication is that the passage from the mouth to the gullet also passes by way of the pharynx. Solid and liquid food passes this way to the stomach, and it is a very wonderful valve system between the trachea and the gullet which controls the passageways for air and food. Should anything happen to make this valve system inoperative, the position in regard to mechanical ventilation is completely changed.

The mechanical breathing machines in use at the present time can be roughly classified under two types—these are :

(1) The negative pressure type, which by replacing inoperative or impaired muscular action, attempts to simulate the normal human respiratory system, or

(2) The positive pressure type, whereby the lungs are directly inflated by intermittent positive pressure, or by alternative positive and negative pressures, through a tube taken directly into the trachea, either by way of the mouth and throat or by way of an orifice specially made in the trachea to receive it.

All cabinet or tank breathing machines (the so-called iron lungs) and all cuirasse respirators, are of the first type.

The second type comprises a wide variety of apparatus, ranging from hand-operated bellows for temporary use, pressure-operated instruments which derive their power from cylinders of compressed air or air-oxygen mixtures, to the most modern machines which are powered by electric motors and can deliver air or air-oxygen at mixtures varying rates, pressures and volumes as desired by the physician.

How the Cabinet or Tank Breathing Machine Works

The cabinet is large enough to take the body of an adult patient. The head and part of the neck are outside the cabinet and the neck opening is made reasonably airtight

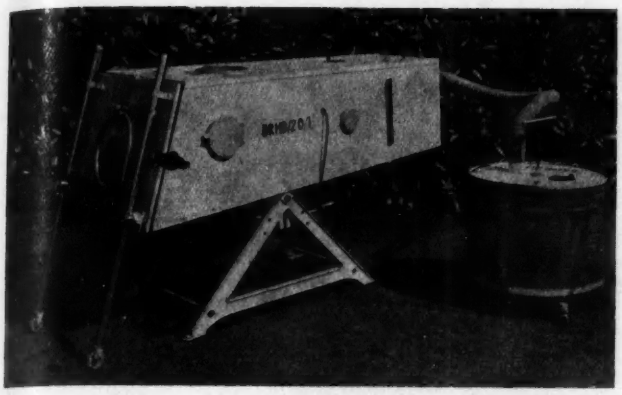


Fig. 2—Original Nuffield Both breathing machine

by some form of soft-rubber sealing collar. A mechanical pump, usually of the crank-driven bellows type, is connected to the cabinet by a short length of non-collapsible rubber canvas hose. An adjustable leak valve is fitted to the cabinet and an adjustable non-return valve to the pump to control the pressure inside the cabinet when the breathing machine is in use.

Fig. 1 is a diagrammatic representation of a modern cabinet breathing machine.

The action of the cabinet breathing machine is as follows : the pump is set to operate at the timed or estimated breathing rate of the patient to be treated. On the suction stroke of the pump about 1·5 cubic feet of air is removed from the cabinet ; this results in a reduction of pressure inside the cabinet and on the body surface of the patient enclosed within it. The patient's head with its breathing openings being still exposed to atmospheric pressure, it follows that air will pass into the lungs and the patient's chest will be expanded.

This is the " inspiration " period of the breathing cycle. For the average adult patient, provided that air passages are clear, the negative pressure required inside the cabinet to cause an air intake of approximately 500 cubic centimetres to the lungs, will be 15-20cm water head.

On the compression stroke of the pump sufficient air is returned to the cabinet to restore atmospheric pressure inside it, the patient's chest returns to normal resting position and an air-carbon-dioxide mixture, in volume approximately equal to that of the air taken in during inspiration, is expelled to atmosphere. This is the " expiration " period of the breathing cycle.

In some cases the physician may decide that for the expiration portion of the breathing cycle, a positive pressure of 5-10cm water head in the cabinet is desirable. This can be obtained with modern machines by adjustment of the non-return valve on the pump. With the usual crank-driven pump the inspiration and expiration periods are equal, but in the opinion of most medical men this is not the best possible breathing pattern. I shall deal with this problem later when describing the design of a new pump unit.

Modifications to the Nuffield Both Breathing Machine

The first meeting of the committee appointed by the Birmingham Regional Hospital Board for the study of mechanical breathing machines, was held in May, 1952, and all types of breathing machines provided in the region were available for inspection. A draft performance specification, issued by the Ministry of Health (Breathing Machines Group) was also available, and, after long and earnest discussion, it was agreed that I should draw up a report to show how far the Nuffield Both machine could be modified to comply with the requirements of the draft performance specification. To encourage (?) me in this work I was warned that a number of the members of the Ministry of Health Breathing Machines Group Committee considered that it was not possible to carry out any worthwhile modifications to the Both machine, while others thought that even if it were possible, it was highly undesirable and would only delay the provision of modern equipment.

A few weeks later, I, together with a medical member of the Birmingham Regional Hospital Board Breathing Machines Committee, visited a London hospital where several machines were in use. The Physician Superintendent gave me every possible help. I was taken to the breathing machines ward and talked with the staff, both medical and nursing. I saw patients in the breathing

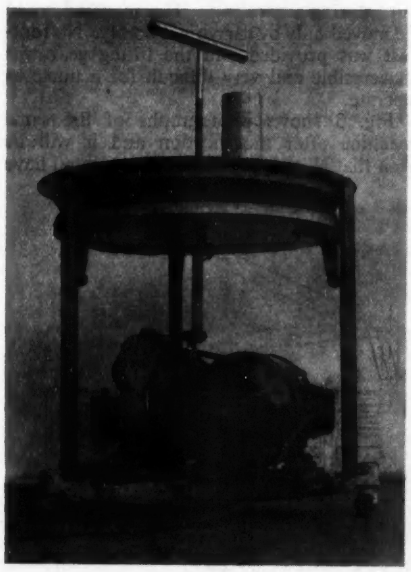
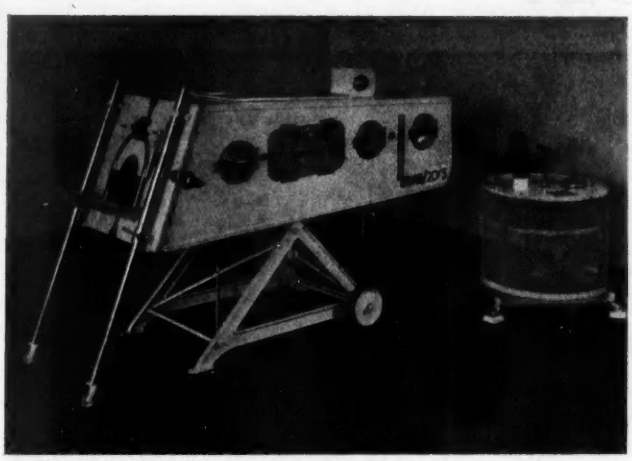
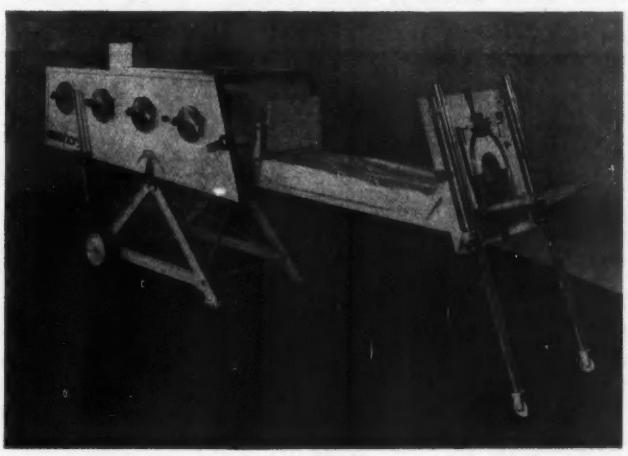


Fig. 4—Original Nuffield Both pump unit

Fig. 5—Modified Nuffield Both pump unit, stage I



(a) Closed.



(b) Open.

Fig. 3—Modified Nuffield Both breathing machine

Fig. 6—Modified Nuffield Both pump unit, Stage 2

machines, and talked with some who were able to be out of the machine for a while. I was able to learn much from that visit, and returned quite convinced that the time for discussion and reports was long past, and that it was up to me to get something done without further delay.

I reported my impressions of the visit to my own hospital management committee, and they very generously agreed to donate £500 from their "free moneys account," to cover the preliminary cost of modifications to the five Both machines held in our own group. Finance being thus assured, I took over a disused air-raid shelter in the Coventry and Warwickshire hospital grounds and, with the help of the senior physicist and a member of his staff, a Nuffield Both breathing machine was completely dismantled. It was found impossible to obtain working drawings and I had to make dimensional free-hand sketches from which I prepared a general arrangement drawing and the detail drawings necessary for the new parts required. Patterns were made and the managing director of Alvis, Ltd., very kindly agreed to have the necessary castings made and machined at what was really a very nominal charge. While this work was being done I machined in my own workshop all the smaller parts required. When all was ready the old Both machine was rebuilt complete with modifications. It was finished in August 1952, and on test proved to be a very satisfactory machine.

Fig. 2 is a photograph of the machine in its original condition. Some may think, as patients have done, that it had a very uncomfortable resemblance to a coffin, and for this reason screens were sometimes placed around so that the patient could not see it when being put in.

Only two hand ports were provided and these were too close to the head end to be of much use. A small circular window gave a very inadequate view of the interior. The valves were very crude —a brass disc, pivoted on a wood screw, sliding over a hole bored in the wooden cabinet served as the negative pressure control, whilst the non-return valve was a rubber disc over a ring of holes and did not provide for the use of positive pressure during expiration. The machine could be moved only by carrying it bodily. No foot-rest was provided and the tilting gear was inaccessible and very difficult for a nurse to operate.

Fig. 3 shows photographs of the same machine after modification and it will be seen that all the deficiencies enumerated have been covered. Four hand ports have been fitted to each side of the cabinet; through these access can be had to the patient without affecting breathing. One large opening, known as the bed-pan door but seldom used for this purpose, is fitted on one side. When this is opened mechanical breathing is stopped. Its main purpose is to allow the passage of anything required for use inside the cabinet and the nurses see to it that it is never kept open for more than a few seconds each time it is used. The small circular window has been moved to the foot end and a large "Perspex" window has been added; this together with the new lighting permits a full view of the whole of the interior. The two strip lights are controlled by separate switches and they can be used to provide some heating if this is required. New control valves have been provided, a screw-operated leak valve on the cabinet to control negative pressure and a screw-controlled non-return valve on the pump unit to control positive pressure. The stand has been strengthened by cross-bracing; two 9in diameter rubber-tyred wheels have been fitted near the rear feet, and non-slip pads fitted to the front feet. The balance is so arranged that the machine can be easily wheeled about by lifting the head end. An adjustable foot-rest has been provided, and a new tilting gear, positive, but very easily operated, enables the cabinet to be set in any position from 10 deg. head end up to 25 deg. head end down (a scale is provided to show position, with a

Fig. 8—Positive-pressure attachment (prototype)

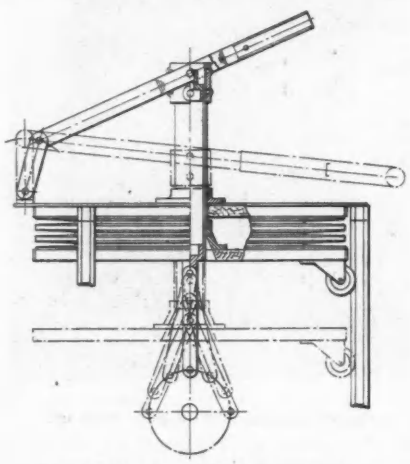
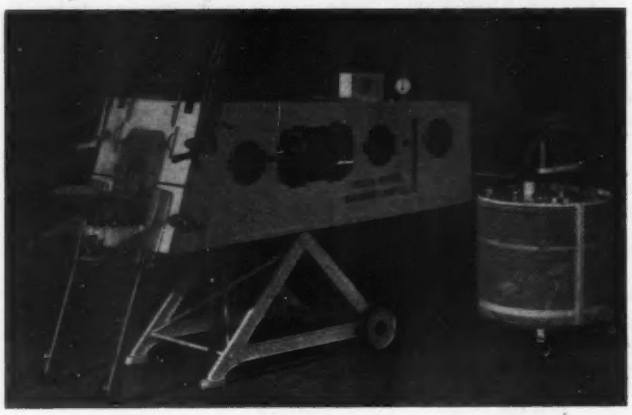
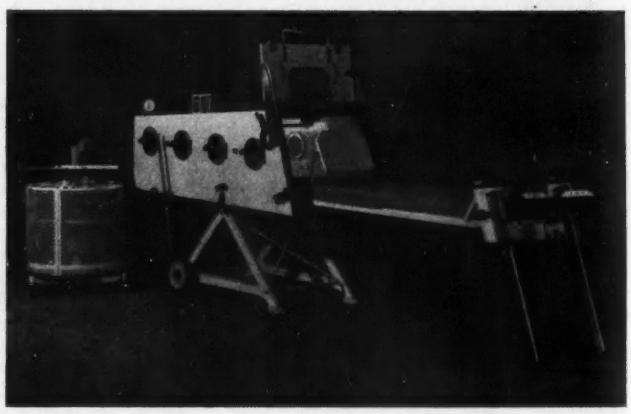


Fig. 7—Modified Nuffield pump unit



(a) Split-head closed.



(b) Split-head open.

Fig. 9—Modified Nuffield Both breathing machine

zero point to enable the cabinet to be set level when it is necessary to withdraw the bed). Holes, closed by tapered rubber bungs, are provided for drip therapy.

A dry-battery alarm system has been fitted; a spring-biased diaphragm operates the contacts and is in communication with the interior of the cabinet by way of a non-return valve with a predetermined leak. Should the negative pressure in the cabinet fall below 10cm water for more than fifteen seconds, a bell will ring and a red light will be shown. This alarm can be put out of action only by raising the lid of the battery box. A switch can easily be forgotten, but even a casual glance will show that the box is open.

Fig. 4 shows a Both pump, cover removed, in its original form. It was a rather primitive piece of mechanism and very noisy. The three-speed pulleys provided only three breathing rates, 20·5, 26 and 32·8 per minute. To permit it to be operated manually, it was necessary to remove the circular cover, and to take out the gudgeon pin, which can be seen just under the bottom bellows board. No mechanical advantage being provided, only a strong man, or better still two strong men, could hope to operate this pump for any considerable period.

Fig. 5 shows the same pump, modified. The modifications are a new baseplate for the motor with easily operated screw traverse and lock for belt adjustment; new pulleys to provide for five breathing rates, 13, 16, 19, 22, and 25 per minute; new bellows guides provided to reduce noise; and a screw-adjusted non-return valve to permit the use of positive pressure. The question of more effective manual operation remained to be dealt with later.

To appreciate the problem fully it is necessary to bear in mind (1) the difficulty (previously mentioned) of removing the motor cover and gudgeon pin; (2) that in the event of electrical failure or power cut at night this might have to be done in total darkness or by the light of a torch; (3) that in such circumstances the power might not have been switched off before removal of the gudgeon pin, with the result that, upon the restoration of current, the connecting rod attached then only to the crankpin would inevitably become jammed and probably some part of the gearbox would be smashed, putting the pump out of action for many hours. Fig. 4 shows pieces of angle iron brazed on to the gearbox to replace the attachment lugs which have been broken off in this way.

Figs. 6 and 7 show how this problem was solved. A suggestion sent to me by a doctor in New Zealand started the train of thought which eventually led to the solution. The central rod of the pump which carried the tee handle is replaced by a 16-gauge steel tube some 2in in diameter; this is rigidly attached to the bottom bellows board, and works in the top bellows board through a guide bearing sealed by a leather packing-ring. To the top of the tube is attached a casting carrying trunnion bearings for the new hand lever, and having holes for a locking pin. A new tee handle, easily attached to the hand lever, gives a total mechanical advantage of 2·15/1, and a nurse can now work the pump by hand, for long periods, without undue fatigue. Working inside the tube is a long piston, the connecting rod being attached to its bottom end; the upper end has a hole with spring-locking arrangement to take the locking pin previously mentioned. When the pin is in position the tube and the piston are locked together and the pump is driven by the crank and connecting rod. With the pin removed for manual operation the piston can move freely in the tube and the system is safe under either condition. The change-over each way can be made in a few seconds. At the time when this modification was made the unreliable rubber bellows were replaced by leather bellows of an improved design.

Fig. 8 shows the prototype of a positive-pressure direct inflation set, designed for attachment to the Both machine. Its purpose is to provide breathing assistance, through control valves and a face mask, when the cabinet is opened for nursing attention or physiotherapy. As it is synchronised with the main pump it can be brought into use before the cabinet is opened; this, together with the fact that the main pump is kept running, is a great comfort to the patient, and enables the necessary service to be given unhurriedly.

Experience obtained in the use of the Nuffield Both machines, modified as described, convinced me that more could and should be done further to increase the comfort of the patient, and to make nursing easier. Fig. 9 shows a further major modification consisting of a split-head board with divided sealing collar, together with an improved fully adjustable head-pillow support, and a new system for guiding and supporting the stretcher bed in the open position. The apparently complicated system for guiding and locating the upper half of the head board was considered to be necessary to prevent any possibility of this latter being allowed to drop on to the face of a helpless patient when it was being lifted or lowered. Unfortunately, the five Nuffield Both machines, the first to be modified, had a very arduous proving test, both clinical and mechanical, during the severe outbreak of poliomyelitis experienced in Coventry during the summer and autumn of 1953. All the machines were in use, two of them continuously for many months, and I am glad to say there were no failures.

The Birmingham Regional Hospitals Board decided to carry out these modifications to all the Both machines in the region; later the modifications were accepted by the Ministry of Health Breathing Machines committee.

(To be concluded)

Research on Automobile Stability

No. III—(*Continued from page* 847, *December* 14)

The Flight Research Department of the Cornell Aeronautical Laboratory has for many years been engaged on the performance of full-scale research on the stability and control of aircraft. A development contract was undertaken for General Motors Research Staff to secure a better understanding of the directional stability and control of automobiles. The lack of flat-road tyre data of a form and completeness suitable for stability and control analyses led to the development of a six-component tyre testing apparatus under a contract with the U.S.A.F.

IT should be pointed out here that though it is now possible, using the relationships derived in papers II and V*, to determine the various stability and control conditions which can be achieved by various factor changes, the designer still has the responsibility for deciding what type of behaviour is best suited to his particular purpose. For the designer to carry out his theoretical consideration of the vehicle steering characteristic he requires to know the following vehicle properties: mass, from the yawing M. of I. the K^2/ab ratio, the wheelbase, and centre of gravity position, and by tyre choice he must establish values for $\frac{\partial y}{\partial \alpha}$ and $\frac{\partial y}{\partial \gamma}$ the cornering stiffness and camber stiffness respectively for the tyres employed in his study.

The cornering characteristics of pneumatic tyres, upon which the stability and control of an automobile ultimately depend, have been investigated under realistic conditions by C.A.L., employing a specially designed machine for the purpose. This machine is referred to as the Air Force-Cornell Flat Road Tyre Tester, and was designed and constructed by Cornell under contract for the U.S.A.F. As its title suggests, the machine sets out to determine tyre characteristics on a flat road surface and, briefly, consists of a six-wheel truck having an additional test wheel mounted overhung at the rear, which can be steered and cambered relative to the vehicle by ±30 deg., and which is loaded pneumatically on to the road surface. The wheel assembly is held on a trailing arm through a load cell arrangement, allowing the 6 force and moment components relative to the plane of the test wheel to be recorded through the medium of strain gauges and electronic recording gear. The historical development and technical details of the equipment are dealt with fully in paper III by Close and Mussey, which is entirely devoted to the subject.

Although developed for the investigation of aircraft tyre behaviour for the U.S.A.F., the tyre tester has also been employed on a programme of automobile tyre tests sponsored by the Dunlop Tyre and Rubber Corporation, of America. The objective in this programme was to determine the effects of predominant vehicle operating variables and of tyre size variables in such a manner that the basic role of the tyre would be emphasised to indicate the choice of a tyre for a given vehicle. The planning of this programme and the interpretation of the experimental results are clearly expounded by Fonda in paper IV. The tyres used in these tests were treadless and of round section, although of conventional carcase construction to avoid as far as possible any indeterminate features contained in the results. Side force and aligning torque were related to the variables; slip angle, camber angle, inflation pressure, and road surface condition, at constant vertical loading. The resultant plots shown indicate that linearity of side force F_y to slip angle α extend to a limit of approximately 4 deg. A conventional analysis of the data obtained employs "cross plots" to arrive at values for the derivatives of various important relationships. $\frac{\partial F_y}{\partial \alpha}$, or cornering stiffness, is related to pressure, and a remarkably close fit is obtained, over the range of 20–30 lb per square inch for all tyre sections tested, to a straight line slope of 3·3 lb per degree per pounds per square inch, all the tyres showing a stiffness of 115 lb per degree at 25 lb per square inch. This slope decreases above 30 lb per square inch, becoming nearly horizontal at 45 lb per square inch. The equivalent stiffness of all sections of tyre (5·00, 6·00, 7·00×16) leads to the unexpected result that

New notation.

D, E—Coefficients of stability quartic.
N.S.P.—Neutral steer point.
T—Period, seconds.
t—Time, seconds.
ζ—Damping ratio.
ψ—Vehicle heading angle.

Subscripts:

F—Front.
R—Rear.
y—Lateral.
z—Vertical.

* "Research in Automobile Stability and Control and in Tyre Performance," I.Mech.E., November 13, 1956.

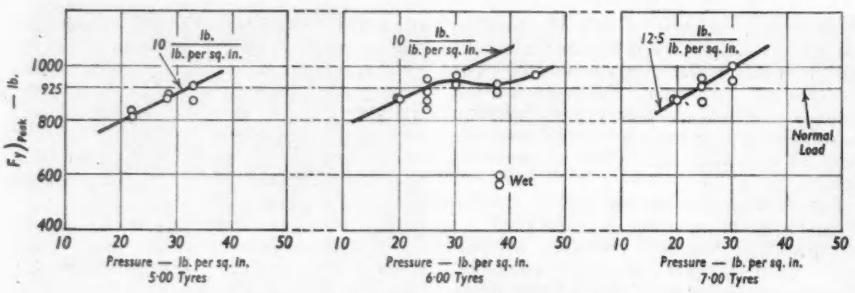

10 lb. / lb. per sq. in.
10 lb. / lb. per sq. in.
12·5 lb. / lb. per sq. in.
Normal Load
Wet
$F_y)_{peak}$ — lb.
Pressure — lb. per sq. in. 5·00 Tyres
Pressure — lb. per sq. in. 6·00 Tyres
Pressure — lb. per sq. in. 7·00 Tyres

Fig. 12—Peak side force for smooth round treadless tyres

section change on one axle of a car will not affect its stability and response.

Similar plots of cornering stiffness against camber are also reported, but show no trends, camber merely altering the $F_y-\alpha$ intercept. Camber thrust against camber angle ϕ† shows a constant slope up to 30 deg. of 20 lb, 16 lb and 17·5 lb per degree for 5·00, 6·00 and 7·00 section tyres respectively.

The relationships found between peak side force and pressure are shown in Fig. 12 and exhibit some interesting properties. First, the maximum force increases at the rate of 10 lb per pound per square inch over the range 20–30 lb per square inch, and, secondly, the friction coefficients obtained (vertical loading=925 lb) increasing beyond unity for dry road conditions, are appreciably higher than normal drum test results. Even the wet road figure of 0·63 is high considering the treadless condition.

Camber was also found to affect peak side force, a typical figure being 2·7 lb per degree, the force increasing with camber of the motor cycle type or decreasing with the roll cambering effects of parallelogram front suspension.

The results of this programme are summarised in the form of derivative values in Table IV.

An interesting use of the unique tyre data obtained on the Dunlop programme is illustrated in Fig. 13, demonstrating the value of derivative notation. In this figure a typical stiffness roll with cornering force of 111 lb per degree is used to draw a car " operating line " across curves for side force against camber angle for different slip angles. This operating line gives the intercepts for the true front wheel operating conditions for the various side force values of a parallelogram I.F.S. layout. A second operating line is also drawn on this figure showing the operating conditions of a motor cycle tyre, the camber here being determined by the equilibrium conditions of the cycle in a turn (i.e. $F=W\tan\phi$).

† Notation of Paper IV.

This result is interesting in showing in a unique manner the fact that beyond 30 deg. of tilt the motor cyclist uses progressively more slip angle, whereas below this value slight negative slip angles are theoretically employed.

The presentation of aligning-torque data up to 30 deg. of slip angle is thought to be unique, and Fonda, after illustrating conventional plotting of this data (aligning torque against side force), introduces an innovation in plotting the pneumatic trail component t of the self-aligning torque $M_s\left(t\cong\frac{M_s}{F_y}\right)$ against side force F_y. This display of t against F_y is illustrated in Fig. 14 and exhibits a near straight line relationship, this form having a physical significance in showing the position of the resultant side force against its own magnitude. The outline of the actual contact patch is also shown in correct relation.

The slope of the t versus F_y plot gives a constant valued derivative $\frac{\partial t}{\partial F_y}$, and since $F_y=\alpha.\partial F_y/\partial\alpha$ up to 6 deg. or 8 deg., M_s and F_y are determined within this range by the three tyre parameters: t_0, $\partial t/\partial F_y$, $\partial F_y/\partial\alpha$, which with $M_z=F_y.t$, may be expressed as: $(\partial M_s/\partial F_y)_0$, $\partial^2 M_s/\partial F_y{}^2$, $\partial F_y/\partial\alpha$, these being a " force-moment derivative " form.

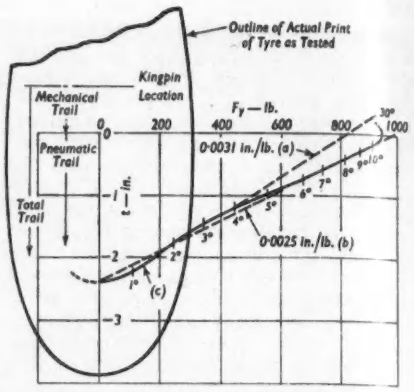


Fig. 14—Pneumatic trail against side force

A combination of tyre behaviour theory and empirical data reveals more significant relationships between tyre performance and its constructional properties. The side force F_y may be put in a non-dimensional form by dividing by F_z, the normal loading. t may be similarly non-dimensionalised by the divisor t_c, the calculated value for pneumatic trail from the theory of lateral tyre deformation giving the relationship:

$$t_c=-l\left[\frac{(l^2/3)+\sigma(l+\sigma)}{(l+\sigma)^2}\right].$$

TABLE IV—*Tyre Derivatives for Three Tyre Sections*

Tyre section	5·00	6·00	7·00	Units
$\frac{\partial F_y}{\partial\alpha}$ [$\alpha=0\pm3$ deg.; $p=25$ lb per sq. in; $F_z=925$ lb]	115	115	115	Lb. per deg.
$\frac{\partial^2 F_y}{\partial p\partial\alpha}$ [$\alpha=0\pm3$ deg.; $p=$ Std. ±5 lb per sq. in; $\phi=0$]	3·3	3·9	3·1	Lb/deg. per lb/sq. in
$\frac{\partial F_y}{\partial\phi}$ [$\alpha=0$; $p=$ Std.; $\phi=0\pm30$ deg.]	20	16	17·5	Lb per deg.
$\frac{\partial(F_y)_{peak}}{\partial p}$ [$p=$ Std. ±5 lb per sq. in; $\phi=0$]	10	10	12·5	Lb/deg. per lb/sq. in
$\frac{\partial(F_y)_{peak}}{\partial\phi}$ [$p=$ Std.; $\phi=0\pm30$ deg.]	2 for $F_y\phi>0$ 7 for $F_y\phi<0$	2·7	2·5	Lb per deg.

(Largest values underlined ; note lack of consistency.)

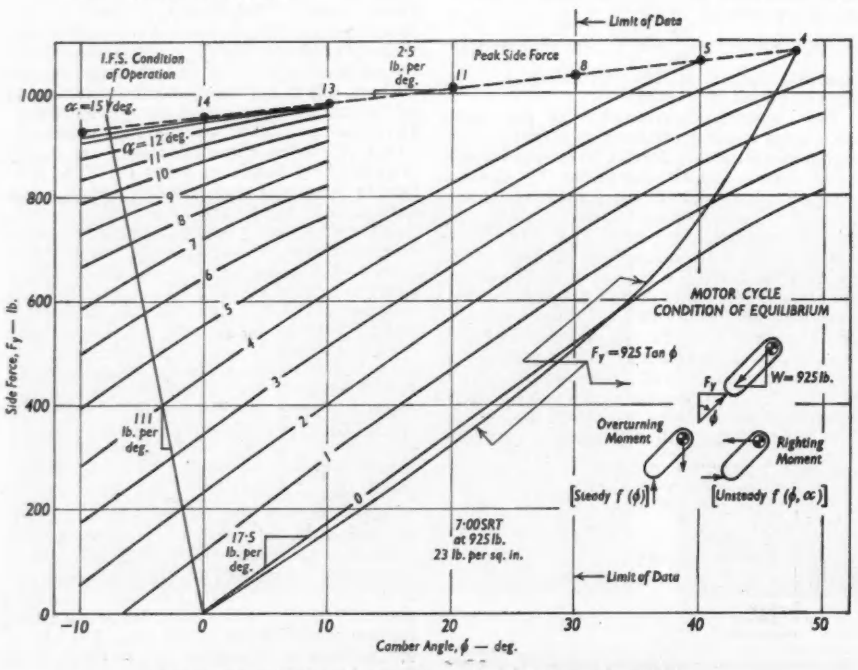


Fig. 13—Side force against camber angle for various slip angles

where l is the half contact length and σ the relaxation length, a stiffness parameter of the tyre.

The theory used predicts a constant value of t_c irrespective of F_y, the observed reduction in trail being due to tyre-to-road slip within the contact patch, not considered in the theory. This decrease is, therefore, an empirical function of the tyre to road friction coefficient μ. Thus, a non-dimensional plot of $\left(\frac{t}{t_c}\right)$ against $\left(\frac{F_y}{F_z}\right)$ consists of a family of curves for various values of μ alone. Such a plot can be considered as a " master curve," valid for a wide range of tyres and conditions, and by making simple laboratory tests for determining the tyre stiffness factors, road handling derivative values may be determined without expensive road testing. Emphasis, in the future, should be placed on the use of tyre theory to interpret tyre data, since it is possible thereby to reveal hidden significances contained therein.

Summarising these five important papers from Cornell Aeronautical Laboratory, which form a " progress report " on their work on vehicle stability problems, it can be said that the introduction of modern control theory into automobile dynamics has been shown not only to explain rationally vehicle steering response behaviour, but also to give valid practical answers within the limits of its application. Finally, it is evident that, to quote Milliken, the direction for further development leading to a yet more complete understanding of the automobile is now apparent.

Development of Gas-Cooled Reactors for Power Production

By R. V. MOORE, G.C., B.Sc. (Eng), M.I.Mech.E., M.I.E.E.

Abstracts are given here from the paper by R. V. Moore which was presented and discussed on November 23 at the final session of the symposium on Calder Works Nuclear Power Plant, held by the British Nuclear Energy Conference in London. The author examines some of the methods of reducing the cost of electricity generated in power plants based on the gas-cooled graphite-moderated reactor. He discusses the effect of fuel temperatures and coolant conditions on performance, bearing in mind the possibilities of dispensing with the steam cycle and using the coolant in a gas turbine. He also looks at the prospects of fuel recycling as a means of reducing the running costs of nuclear power generation.

IF the Calder plant was run as a power station, and no value was attributed to the residual plutonium, it would produce electricity at about a penny per unit. This would not be competitive with coal-fired stations in the United Kingdom, and so in future plant this cost must be reduced. It is pertinent, therefore, to analyse the factors which contribute to the cost of electricity and establish how this vital reduction may be achieved.

As with conventional plants, the cost per unit may be taken as the sum of the capital charge, the fuel charge and the cost of operation and maintenance.

TABLE I—*Cost per Unit*

Cost component	Cost d	Per cent
Capital charge	0·56	53
Fuel inventory charge	0·10	9
Fuel consumption charge	0·35	33
Operation and maintenance	0·05	5
Total	1·06	100

Table I shows the composition of the cost per unit from the Calder Works if the plant were operated at 80 per cent load factor as a nuclear power station and the fuel irradiated to an average value of 3000 MWD/tonne, it being assumed that the fuel elements cost £20,000 per tonne. This assumes that the uranium is passed once through the reactor; the possibilities of fuel recycling are considered later in the paper. No value is attributed to the residual plutonium.

As with all power-producing plants, a high load factor leads to a reduction in the capital charge component of the cost per unit. With a nuclear plant of the type under consideration an additional component—the fuel inventory charge—is similarly affected. These plants, passing through a phase of high capital cost, are therefore suitable as base load units. This happens to accord in the United Kingdom appropriately with the necessity to generate as much power as possible from resources other than coal. To operate at a high load factor implies a high order of plant availability and no doubt the design of future nuclear power stations will incorporate improvements over the Calder Works in this respect, e.g. charging and discharging uranium while the plant is operating at power.

The only factor to which the whole unit cost is proportional (in the inverse ratio) is the overall efficiency η, and small improvements are therefore important. Fig. 1 is a plot of the cost per unit sent out from a nuclear power station costing £125 per kilowatt (s,o.), operating at 80 per cent load factor and 25 per cent efficiency, as a function of the MWDs of heat removed from each tonne of uranium costing £20,000 per tonne, assuming the fuel elements have no residual value. The importance of being able to irradiate the fuel for as long as possible is obvious; particularly striking is the way in which the cost per unit falls rapidly up to about 2000 MWD/tonne.

The ability of a natural uranium charge to achieve a long irradiation depends mainly on two factors: first, the neutron balance, necessary for the chain reaction, must be maintained; and secondly, the fuel elements must withstand the effects of irradiation damage under the operating conditions, without an excessive number of failures. As the ^{235}U content of the charge is consumed it is replaced to some extent by plutonium formed from ^{238}U by neutron capture, and a small fraction of the plutonium so formed is itself fissioned. Recent experimental results from the Calder plant tend to confirm that 3000 MWD/tonne is obtainable before poisons accumulate in the fuel elements to the extent of inhibiting the chain reaction. The metallurgical limits on the life of the fuel elements arise from the tendency of uranium to increase in volume when irradiated at temperatures approaching the alpha/beta change point of 660 deg. Cent. Knowledge of the extent of this increase is not at present complete, but there is mounting evidence that 3000 MWD/tonne is attainable. Indeed, it is likely that this limit and the operating temperature may be raised by the adoption of certain alloys of uranium stabilised in the gamma phase.

DEVELOPMENTS FROM THE CALDER PLANT

The performance of the Calder plant was limited primarily by two design factors:—

(i) The thickness of steel plate from which the reactor pressure vessel is constructed, which determined the pressure of the CO_2 gas and size of the reactor.

(ii) The maximum temperature of the system.

The diameter of the reacting core was chosen so that the plant would operate at full power using natural uranium fuel, with a small excess reactivity for satisfactory control. This consideration in conjunction with the selection of steel plate 2in thick for the construction of the cylindrical pressure vessel fixed the operating pressure of the CO_2 gas at 100 lb per square inch gauge. The maximum temperature of the system was set by the temperature below which the uranium fuel elements would reliably operate. This was judged to be 400 deg. Cent. (752 deg. Fah.) at the surface of the hottest fuel elements. The economic performance of this type of plant improves as these limits are raised.

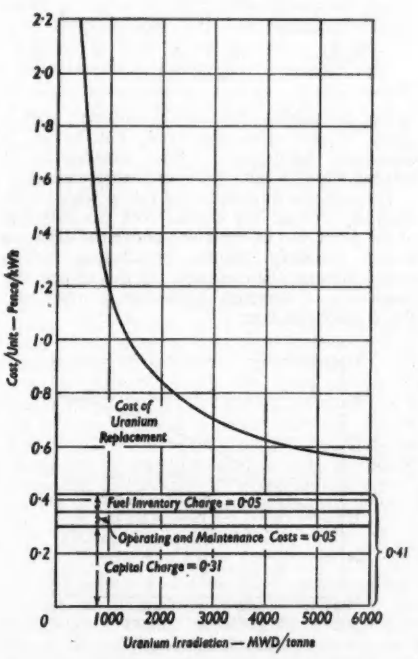


Fig. 1—Cost per unit sent out as a function of MWD per tonne

Effect of Increasing the Plate Thickness of the Reactor Vessel.—Visualise a graphite core with the uranium channels located on a square lattice, surrounded by a graphite reflector 3ft thick within a cylindrical pressure vessel, with 1ft radial clearance between the inside of the pressure vessel and the graphite; it can be shown that

$$Q=\frac{0\cdot113(d_P-8)^3q\alpha}{p_s^2} \quad . \quad . \quad . \quad . \quad (1)$$

where

Q=heat rate of the reactor, MW.

q=heat output of most highly rated uranium channel.

d_P=internal diameter of pressure vessel, feet.

p_s=pitch of uranium channels, inches.

α=radial form factor of neutron flux, mean/maximum.

The diameter of the reacting core of the Calder reactors is chosen so that the reactor is just supercritical at full power. Therefore a core of similar design and nuclear properties, whose diameter is greater will have excess reactivity above that required for operation of the plant. This can be profitably exploited by introducing absorbing material into the core in such a way that the neutron flux is flattened and the value of α raised. Thus increasing the pressure vessel diameter, d_p produces marked increases in Q, not only because of the increased number of channels, but also because of increases in the value of α.

It is interesting to note from equation (1) the importance of maximising q. In practice this must be done in relation to ϕ, the ratio of pumping power to q, and the temperature rise ratio r. The effectiveness of the extended surfaces for heat transfer from the fuel elements to the coolant is important in this facet of reactor design. It can also be seen from equation (1) that Q is increased as the lattice pitch p_s is decreased, but this has repercussions on the nuclear and mechanical design. Squeezing the lattice can only be exercised profitably over a limited range.

Before relating Q to the design of the reactor vessel, it is necessary to assess the effect of the absolute pressure of the circulating gas. Increasing the gas pressure reduces the fraction of the reactor heat rate required for the gas circulation according to an inverse square law. Increasing the pressure therefore brings diminishing returns.

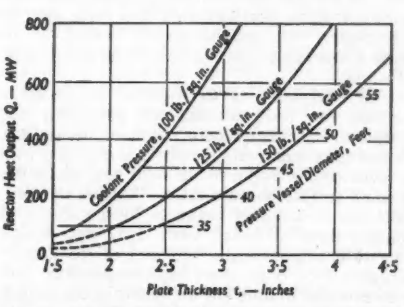


Fig. 2—Results for varying gas pressures values of q and p_s for constant values of ϕ

The final selection of the best value must be related to the optimisation of a specific design of plant. In considering limited extrapolations from the Calder design, however, it is sufficient to consider an increase of, say, 25 to 50 per cent. Taking values of gas pressure in this range, and assuming a cylindrical pressure vessel, it is possible to evaluate equation (1) to give values of Q following increases in reactor vessel plate thickness.

Typical results are plotted in Fig. 2 for gas pressures of 100 lb, 125 lb and 150 lb per square inch gauge, taking values of q and p_s, from the Calder design of core, for constant values of ϕ, the ratio of pumping power to q. The marked

effect of increasing the thickness of the pressure vessel wall on the heat rate of the reactor can be clearly seen. For 3in thick plate, for example, the heat rate of the reactor could be 400–500MW. It is obvious that the capital cost of the plant would increase proportionately much less than this increase in heat rate and so the capital cost per kilowatt could be expected to drop considerably from the figure for the Calder plant.[2]

The above is a somewhat over-simplified approach to assessing the effect of increasing the size of the reactor. For example, there are several alternatives to a simple cylindrical pressure vessel fabricated in mild steel. But in general it can be concluded that increases in size, accompanied by limited increases in gas pressure, materially reduce the cost per kilowatt, without the need for further scientific or technical developments. This has immediate importance as nuclear power stations can be built of improved performance whose reliability is underwritten by the operating experience of the Calder Works.

Effect of Increasing Maximum Temperature of the System.—Development in the direction of higher temperature operation is particularly interesting.

For service in a reactor the uranium is clad with a metal of low neutron cross-section, to prevent escape of the radioactive fission products into the closed primary coolant circuit and to prevent any chemical reaction between the uranium and coolant. The main possibilities are shown in Table II. Stainless steel (18/8/1) has been included, although its neutron cross-section is relatively much higher than the other possibilities.

TABLE II—*Possible Uranium Cladding Materials*

	Aluminium	Magnesium	Beryllium	Niobium	Zirconium	Stainless steel (18/8/1)
Neutron cross section, cm^{-1}	0·0118	0·0023	0·00011	0·061	0·0076	0·227
Melting point, deg. Cent.	660	650	1284	2415	1850	1500
Thermal conductivity, C.H.U./h .ft. deg. Cent.	130	90	70	36·4	14·4	9·2
Density at 20 deg. Cent.	2·7	1·74	1·85	8·57	6·5	7·9

This table shows that it is not possible to raise the maximum temperature of fuel elements, clad in either magnesium or aluminium, much above the value of 400 deg. Cent. (752 deg. Fah.) adopted for the Calder plant, owing to the low melting point of these cladding materials. Note also that the alternative materials Be, Nb, Zr and stainless steel have values of thermal conductivity considerably worse then either Al or Mg. This, coupled with the increased heat-flux associated with the desired higher rating of the fuel, means that the fin efficiency of any extended surfaces, from fuel elements clad with one of the higher melting-point metals, would fall to such a low value that the fins would cease to be effective.

The alternative is to increase the primary surface for heat transfer by spreading the uranium. This has repercussions on the nuclear design since maximum reactivity is obtained with a fuel element shape, like a solid rod, which has a small surface-to-mass ratio. Raising the temperature of the fuel elements by a substantial margin from 400 deg. Cent. (752 deg. Fah.), therefore, implies a discontinuity of the present design. Not only must high-temperature fuel elements clad in little known metals be developed, but a change in shape is involved which probably necessitates the use of enriched fuel.

It is pertinent to make a rough assessment of the effects of increased temperature. Let a fuel and single channel geometry be assumed, say, a uranium configuration increasing the surface-to-mass ratio by a factor of 3 over the solid rod case, and a channel 20ft long through which CO_2 at a pressure of 150 lb per square inch is pumped. Further, assume that the gas enters the channel at 200 deg. Cent. and that the ratio ϕ is 2 per cent. Fig. 3 shows the variation of the channel heat rate q, the channel gas outlet temperature T_2, and the average rating of the uranium m in the most highly rated channel, against the maximum surface temperature of the fuel T_{sm}.

The beneficial effects of increased fuel element temperature on the performance of the reactor are at once apparent. The rising values of channel gas outlet temperature from the reactor enable the overall efficiency of the plant to be raised. The channel gas outlet temperature is higher in the less highly rated channels of the reactor, so that the mixed or bulk gas outlet temperature is somewhat higher than the values of T_2 plotted in Fig. 3. Making some assumptions which are typical of this type of plant, Fig. 4 shows the variation of overall efficiency against the bulk gas outlet temperature T. Raising the maximum fuel-element temperature, therefore, increases the rating of the reactor and the overall efficiency of the plant.

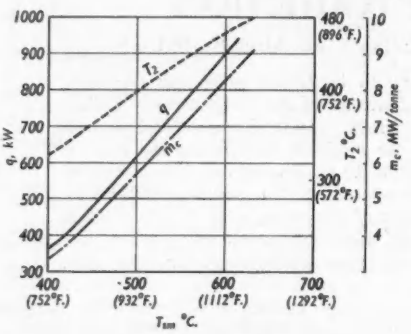


Fig. 3—Variation of channel heat rate q, channel gas outlet temperature T_2 against maximum surface temperature of the fuel

Using data from Figs. 3 and 4 and evaluating equation (1) with appropriate value of p_2, Table III compares an extrapolated Calder design, having a reacting core 40ft in diameter, with a plant of the same size core, but having a maximum fuel-element surface temperature of 600 deg. Cent., a value little better than a guess.

TABLE III—*Comparison of Extrapolated Calder Design (Case A) and Plant with Maximum Fuel-Element Surface Temperature of 600 deg. Cent. (Case B)*

	Q_r, MW	π_2, per cent	m, MW/tonne	Q_E, MW
Case A : Larger Calder design	400	25	2	100
Case B : High - temperature reactor :				
(i) Flattened ...	1400	31	5·8	433
(ii) Unflattened...	1100	31	4·5	340

The increase in output and rating would substantially reduce the capital cost per kilowatt of the plant, but as explained above the uranium would probably require enrichment, which would increase the fuel cost. In this respect the possibility of recycling plutonium is relevant ; this is discussed later.

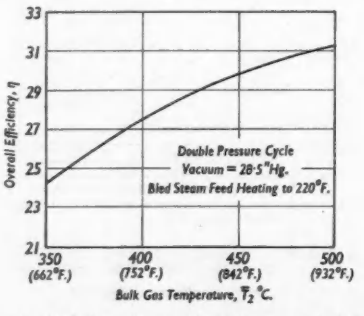


Fig. 4—Variation of overall efficiency against bulk gas outlet temperature $\bar{T}$

The heat rates from the reactors in cases *B* (i) and (ii) are rather large from a single unit and in a specific design it might be beneficial in optimisation, to decrease the core diameter, raise the gas pressure of the system and use larger temperature differences in the heat exchangers. This would reduce the size and cost of the external CO_2 circuit, including the heat exchangers, and produce a more balanced design, which would be reflected in a favourable cost per kilowatt for the plant, even if the net output was reduced.

The development of gas-cooled reactors has been focused in the United Kingdom so far on the base-load application. The substantial increase in fuel rating m obtained by high-temperature operation increases the economic feasibility of plants of lower power output and for lower load factor, using slightly enriched fuel.

The difficulties associated with the development of a high-temperature plant should not be underestimated. The basic compatibility problems are again thrown into sharp relief. CO_2–uranium, CO_2–graphite, CO_2–steel, CO_2–canning material reactions all enter a more active phase. The successful development of fuel elements (using a cladding metal on which experience is limited) to withstand the damage of long irradiation at high temperature requires extended application of very substantial resources.

Fuel Economy

So far in this paper, the basic type of reactor considered has been one operating on natural uranium on a " once-through " system. On the basis of the White Paper[1] it is apparent that by 1963–64 onwards, by-product plutonium will be produced in substantial quantities. According to the economy attained by the first plants, the cost of the plutonium, when separated from the irradiated fuel, will be less than the cost of producing uranium enriched in ^{235}U by the diffusion plant process.

Apart from this possible economic incentive, there is a strong urge to use this fissile material since by so doing conservation of nuclear fuels is improved. Inevitably the question arises of how by-product plutonium may most profitably be used, once supplies have been established. There appear to be at least four important possibilities :

(i) It could be used in new thermal reactors requiring initial enrichment, e.g. high-temperature gas-cooled reactors referred to in the preceding section.

(ii) It could be used in fast-neutron, breeder reactors operating on a Pu–^{238}U cycle and producing power. This leads to balanced fast and thermal reactor schemes in which a comparatively large fraction of the ^{238}U is used, arising from the fact that fast reactors breed more fissile material than they consume.[3] An experimental fast reactor is currently under construction at Dounreay, in the North of Scotland.

(iii) It could be used in fast or thermal reactors as the fissile material for a Pu-Th " transition cycle " producing power and ^{233}U as a by-product. The ^{233}U might subsequently be used in a self-sustaining ^{233}U-thorium cycle in thermal reactors, if these prove practicable, or might be used as the fissile material in fast reactors, breeding from ^{238}U or thorium.

(iv) It might be used in power plants requiring highly enriched fuel, e.g. plants designed with a large power/weight ratio.

As this paper is considering developments in gas-cooled reactors, possibility (i) above is examined in more detail.

Fuel Recycling

In a thermal reactor fuelled with uranium, ^{235}U is fissioned and some of the ^{238}U is converted by neutron capture into ^{239}Pu, which is fissile to thermal neutrons. By neutron capture higher isotopes of plutonium are also formed and constitute an important fraction of the plutonium. On a " once through " system in which the charge is irradiated up to, say, 3000 MWD/tonne, a small proportion only of the plutonium is burnt and the discharged fuel elements contain plutonium, depleted uranium and fission products. In chemical separation plants, similar to the full-scale plants which the U.K.A.E.A. have now been operating for some years, the constituent parts

can be separated. The possibility therefore arises of returning the plutonium and part of the depleted uranium to the fuel element fabrication factory, there to be reconstituted with new feed uranium into fuel elements for charging into the reactor.

The effect of fuel recycling may be illustrated by specific example. Consider the reactor associated with case B (ii), Table III, operating on an equilibrium cycle, each successive charge being irradiated to 3000 MWD/tonne. For this case each tonne of natural uranium make-up would produce 8500 MWD of heat, or the utilisation of uranium fuel resources would be improved over the once through system by a factor of 3. The reactor design chosen in this example is not particularly well adapted to operate on fuel recycling and this factor might conceivably be increased, by a design more appropriate for this system of fuelling. It is clear that potentially the important advantages of fuel recycling are :—

(i) It could reduce the natural uranium requirement to meet a given power demand by a significant factor.

(ii) Under certain conditions, applicable to gas-cooled graphite-moderated reactors, designs requiring initially a charge of slightly enriched uranium can be subsequently fed with natural uranium once equilibrium conditions are reached.

An economic assessment of fuel recycling at the present time cannot be made with any exactness. The effect of holdup of fuel in processing, the relative quantities in the reactor and "pipeline," and the effect of processing rate/feed rate are some of the factors involved. The cost of fabricating fuel elements with α-active plutonium is another important factor in determining the overall economy of fuel recycling.

Comparison of Various Gases as Coolants

The only satisfactory way of comparing the performance of different gases is to evaluate for a specific design. In general, when this is done the differences are not so marked as expressions like M^2, $c_p{}^3$ (where M=molecular weight and c_p=specific heat) suggest. CO_2 was the gas chosen for the Calder Hall reactors because it was the best compromise between all the requirements. As the temperature of reactor systems is raised, new conditions will be created and helium or nitrogen may supplant CO_2, as, comparatively, they are inert gases. Hydrogen is inert at ordinary temperatures but is chemically active at elevated temperature, and further is a highly inflammable gas. Considerable research work would have to be carried out before its feasibility was established for cooling nuclear power reactors ; however, its superior heat transfer properties and favourable nuclear properties are a considerable incentive.

Non-Metallic Fuel Elements

As the temperature at which the fuel elements are designed to operate is raised, interest is stimulated in ceramic fuels, i.e. compounds of uranium, plutonium and thorium with oxygen and carbon. The properties of uranium, uranium carbide and uranium oxide are compared in Table IV.

Table IV—*Properties of Uranium, Uranium Carbide and Uranium Oxide*

	U	UC	UO_2	UC_2
Melting point, deg. Cent.	1133	2250	2500	2260
Density	19	13·5	11	11·28
Thermal conductivity at 50 deg. Cent., C.H.U./h ft deg. Cent.	3·75	4·6	0·29	0·47

Compared with the metals, they have much higher melting points, are brittle, and soften only at comparatively high temperatures. Most ceramics have a thermal conductivity much lower than metals but this is not the case with the uranium carbides, which have similar values to the uranium metal.

Uranium oxide was used in the first reactor built in the United Kingdom (GLEEP) but uranium metal was later preferred as its density is higher, a favourable property from the nuclear point of view, particularly important when natural uranium is used. As concentrated fissile materials become available, however, interest in the ceramic forms of uranium will probably return. Generally speaking, ceramics are more resistant to coolant attack than metals. UO_2 is inert both to CO_2 and hydrogen. UO_2 and UC are reasonably stable in air although UC_2 and ThC_2 are very reactive. In addition to their favourable high temperature properties, there is some experimental evidence to indicate that their irradiation resistance is considerably better than the metal.

Very-High-Temperature (V.H.T.) Reactors

Ceramic fuels and the fact that graphite itself is a refractory material have led to the possibility of a very-high-temperature, gas-cooled reactor, in which all metals are excluded from the core. This type of reactor has been given considerable impetus recently by Fortescue of Harwell. As a type it might be developed to meet the requirements of groups (iii) or (iv) of the section on "Fuel economy."

Fuel rating is generally discussed in terms of heat removed from a given mass of uranium (MW/tonne), a small proportion only of which, in natural or slightly enriched uranium, is fissile material. This definition of rating carries with it a concept of the size of the plant ; possibly some 20 per cent of the capital cost of a plant is inversely proportional to this figure. The fuel inventory charge is also reduced as the rating is increased. Another way of expressing fuel rating is in terms of fissile material, a concept more important in relation to fuel cycles. With natural uranium the fissile material rating is 140 times the uranium rating. Table V shows the uranium and fissile-material ratings for the reactors discussed in this paper.

Table V—*Uranium and Fissile-Material Ratings*

	Uranium rating, MW/tonne	Fissile material rating, MW/kg
Calder Works	1·4	0·2
Case A of Table III	2·0	0·3
Case B (i) of Table III... ...	5·8	0·8
Possible V.H.T. reactor ...	—	1–2

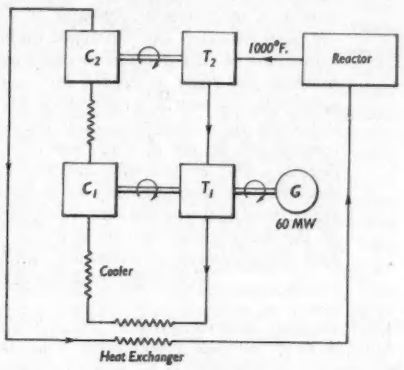
With the V.H.T. reactor the possibility exists of virtually "diluting" the fissile material with the moderator; in this case high fissile material ratings are possible (see Table V) and at the same time good neutron economy is preserved.

At the high temperatures associated with this type of reactor (typically, a gas outlet temperature of 800 deg. Cent. (1472 deg. Fah.)) the problems associated with materials are acute. Attaining a high degree of thermal and irradiation stability of the graphite and the ceramic fuel at high temperature and high neutron flux presents a formidable research problem. So does preventing the spread of fission products into the primary cooling circuit. These ideally should be confined to the fuel, as with conventional fuel elements, clad in metal. The incentive for development, however, is high. It is calculated that the overall efficiency of such plants could exceed 40 per cent, while the high fuel rating would lead to a further reduction in the capital cost per kilowatt, when compared with high-temperature reactors with metallic cladding of the fuel elements, as typified in case B (i) of Table III.

Gas Turbine Cycles

The prospect of higher gas temperatures leads inevitably to the consideration of gas turbine cycles. For plants of large power output, a cycle of the same general type as developed by Escher-Wyss is applicable. Stenning and Howieson, of Chalk River, Canada, have carried out preliminary calculations for this type of plant, the general layout of which is shown in Fig. 5. The hot gas from the reactor feeds high and low-pressure turbines, the latter driving the alternator. Two-stage compression with intercooling is used, the h.p. and l.p. compressors being driven by the h.p. and l.p. turbines respectively.

Comparing the merits of CO_2 and helium, Stenning and Howieson conclude that the rotating machinery for the CO_2 cycle has approximately half the volume of that required for the helium plant, but the heat exchangers have nearly double the volume, which suggests that marginally the CO_2 plant might be cheaper to build. In carrying out preliminary design calculations for a 60MW (electrical) plant they assumed a gas pressure of 300 lb per square inch absolute and a top gas temperature of 1000 deg. Fah. (538 deg. Cent.). These conditions are particularly interesting as they probably represent something near the minimum conditions for such a cycle, the machinery being large and costly yet possible to design and construct. Even at 1000 deg. Fah. (538 deg. Cent.) the calculated efficiency



T_2—H.p. turbine.
C_2—H.p. compressor.
T_1—L.p. turbine.
C_1—L.p. compressor.

Fig. 5—Gas-turbine cycle

is 29 per cent, and if this temperature was raised to 1250 deg. Fah. (677 deg. Cent.) this would go up to 38 per cent. For the capital cost of the plant to be competitive with steam plants it would appear, however, that the system pressure would have to be considerably higher than 300 lb per square inch gauge.

Potentially the gas turbine cycle becomes worth while in conjunction with the V.H.T. type of reactor, but for the system shown in Fig. 5 to be feasible, fission products would have to be contained within the reactor.

Summary and Conclusions

It must be remembered that this paper discusses the possible developments of one particular class of reactor—the gas-cooled, graphite-moderated type, and therefore reviews the future on rather a narrow front. These plants, fuelled with natural uranium, however, are the spearhead of the United Kingdom's nuclear power programme. Incorporating many detail improvements, the first series basically will be larger versions of the Calder Hall plant.

The performance improves rapidly as the design value of the fuel element temperature is raised, the capital cost per kilowatt is reduced through increased fuel rating, the unit cost being further decreased as the efficiency rises. The solid rod fuel element, clad in magnesium or aluminium, is reaching the end of its possible development. A new range of reactors is opened up with the introduction of fuel elements with larger surface-to-mass ratios, and clad with a metal of high melting point. These reactors will probably need initial enrichment, although their design may well enable them to operate on recycled fuel with a natural uranium feed. The higher ratings possible with these designs may extend the field of application from base-load power plants to plants producing smaller amounts of power at a worthwhile cost.

Still higher temperature systems may be developed in which metals are excluded from the core, the fuel being ceramic and dispersed in the graphite moderator. Many severe problems are associated with this design, but successful development would lead to still cheaper power and to compact systems for which gas turbine cycles would be economically feasible as an alternative to steam.

References

[1] *A Programme of Nuclear Power*, Cmd. 9389, 1955, February (London : H.M. Stationery Office).
[2] R. V. Moore, R. J. Haslam, G. Duffett and G. Packman, *A 200MW Nuclear Power Station*, A.E.R.E. Report, 1954, August, No. UK/C.
[3] C. A. Rennie, "Economic Power from Fast Breeder Reactors," *Journal Nucl. Energy*, 1954, 1, page 39.
[4] J. V. Dunworth, "Fuel Cycles and Types of Reactor," *Proc. Int. Conf. Peaceful Uses Atomic Energy* (Geneva, 1955), Paper No. P/403, 1956, 3, page 14.

Machine for Determining Vibration of Precision Ball Bearings*

By H. L. WUNSCH, M.Eng., A.M.I.Mech.E

In view of the increasing use of small precision ball bearings, running at high speeds, it was thought desirable to develop a machine for testing these bearings for both vibration and frictional torque. In order to simplify the design of such a machine, it was decided to carry out the two tests separately. Accordingly, a machine has been developed for continuously recording the frictional torque in precision ball bearings running at high speeds and under various loads, and this has been fully described in a previous article.† Further work has now been carried out on the development of a machine for determining vibration in ball bearings, and the following article describes the construction and operation of this machine. It had originally been intended to measure airborne noise rather than vibration, but it was felt that the difficulties in doing this would be excessive in view of the presence of various sources of external noise. It was therefore decided that measurement of vibration, while presenting fewer difficulties, would still provide the required data concerning the ball bearing.

THE machine described in this article (which is of much simpler construction than the friction testing machine) is capable of running ball bearings of 5mm or 10mm bore at speeds up to 60,000 r.p.m. and under separate or combined axial and radial loads of up to 20 lb. The vibration of the ball bearing is measured in a radial direction and an electrical output signal proportional to this vibration is provided. Facilities for accurate measurement of speed are also available.

Construction

High-Speed Motor.—The driving unit for this machine is a high-frequency motor mounted on air lubricated bearings of similar design to that used in the friction testing machine and is fully described in the above-mentioned article.† As before, the motor, which is slightly smaller than the previous one, was run for several hours at 60,000 r.p.m. and was found to be perfectly satisfactory.

High-Speed Air Bearing.—Utilising the experience gained in the development of the friction testing machine, the high-speed air bearing has been modified for the purposes of this machine. In order to satisfy the specification of 20 lb axial and radial load at the bearing under test the size of the air bearings has been increased. Since this load is applied asymmetrically, it was

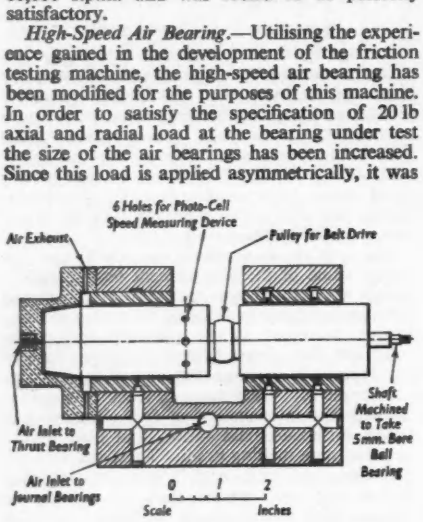


Fig. 1

decided to make the bearing nearest to the applied load larger than the other one, and in the present design the bearings are in fact 1½in diameter by 2in and 1½in by 1in respectively. The smaller bearing is supplied by one row of three admission holes of 0·025in diameter, equally spaced. The larger bearing has two rows of admission holes ¼in from each end. Each row contains three equally spaced holes of 0·025in diameter with an additional fourth hole of 0·010in diameter at the bottom of the bearing. This bearing is made in this way because the design of the machine ensures that it will always be loaded in a downward direction. The radial clearance in the bearing is of the order of 0·001in. With this arrangement of air admission holes and clearance it was found that a load of up to 25 lb could be applied at the ball bearing under test. An additional feature of this new design is that the pipework of the previous air bearing has been replaced by internal air passages, so that only one air supply point is sufficient for all the radial bearings. This is clearly shown in both the sectional drawing, Fig. 1, and the view of the machine, Fig. 2.

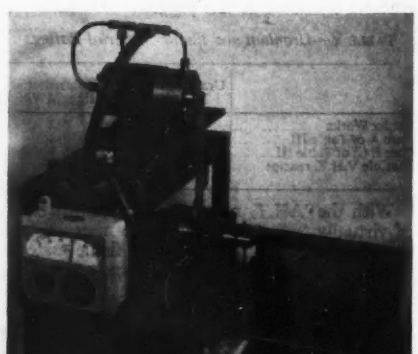


Fig. 2

The thrust bearing used in the machine is of the same design as on the friction test rig ; that is, with conical escapement and one central admission orifice of 0·030in diameter. This also appears in Figs. 1 and 2.

Belt Drive.—As in the previous machine, the drive is transmitted from the high-speed motor to the air bearing shaft by means of a linseed oil impregnated tussah silk belt. The motor is mounted on a platform which can be tilted about a hinge at one end, so that the belt tension can be readily adjusted.

Ball Bearing Housing.—The design of the ball

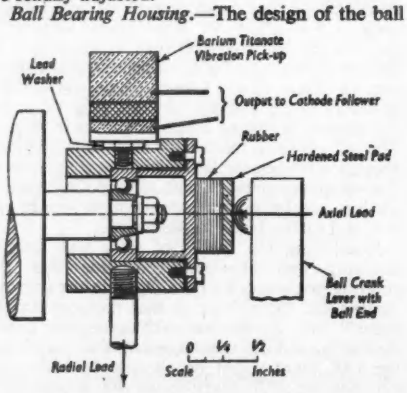


Fig. 3

bearing housing in this machine is of very simple form, as can be seen from the sectional view of Fig. 3. The outer race of the ball bearing is a sliding fit in the housing and bears axially against a square shoulder. It is held in position by an axial clamp. In view of the simplicity of this design it was decided not to use adaptors for different sizes of ball bearings, but to provide separate housings. In this machine it was considered permissible to apply the required axial and radial loads directly to the ball bearing housing. The radial load is carried directly on a weight carrier attached to the bottom of the housing. The axial load is applied by direct loading through a system of levers, finishing with a ball-ended contact on the centre line of the ball bearing housing. A rubber pad is placed between the end of the housing and the ball in order to

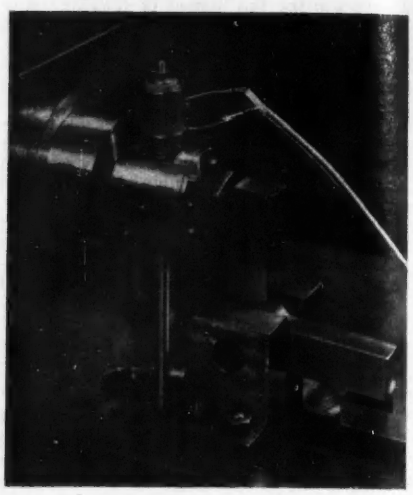


Fig. 4

allow the ball bearing outer race and hence the housing to vibrate freely. This can be seen in the pictorial view, Fig. 4.

Speed Measurement.—The speed of the main air bearing shaft is measured photo-electrically Three equally spaced holes, about ¼in diameter, are drilled diametrically through the shaft, thus giving effectively six passages per revolution. Light from a small light source is arranged to shine through these holes on to a type 90A germanium photo-cell placed on the other side of the shaft ; this results in six electrical impulses given out by the photo-cell per revolution and these, after being amplified, are applied to a suitable counting instrument of either the frequency monitor or the frequency meter class. Thus a direct reading of speed can be obtained. The general arrangement of the speed measuring equipment can be seen in Fig. 5.

Vibration Measurement.—After due consideration of the conditions under which the vibration measurements had to be carried out it was decided to use a piezo-electric pick-up of the barium-titanate type. This consists of a small disc of barium-titanate type, held between a metal base and a comparatively large metal mass. If the base is subjected to forced vibrations the disc undergoes a cycle of alternating stresses, since the inertia of the metal mass tends to keep it stationary in space. The alternating stress in the disc causes a voltage to be generated between the top and bottom face of the disc, and this voltage is proportional to the force applied and hence to the acceleration component of the vibration. The advantages of this type of pick-up are its comparatively high output for quite a small size, and this latter fact makes it especially suitable for this application.

Two forms of construction were tried out (Figs. 6*a* and 6*b*), and both proved to be equally satisfactory. In the first, the base, the disc and the metal mass were held together by means of "Araldite," which is a hot setting resinous adhesive. In the second type the disc and metal mass had a central hole and were bolted together by means of a stud machined integral with the base. In this case, the mass had, of course, to be insulated

* Communication from the Mechanical Engineering Research Laboratory, East Kilbride, Glasgow.

† THE ENGINEER, 1954, 198, 732–734.

from the stud. In both forms, the electrical connections were made by means of two wires soldered to the mass and the base respectively. The bottom of the base was finished in the form of a 4 BA screw which could be directly screwed into the ball-bearing housing; the top of this housing was machined flat and a lead washer

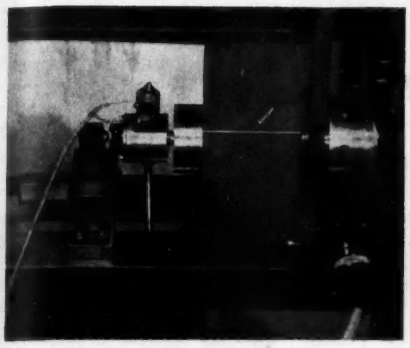


Fig. 5

placed between it and the pick-up to obtain satisfactory mechanical contact.

This type of pick-up requires polarisation, which is carried out as follows. The pick-up is heated in a suitable oven and preferably in an oil bath to about 110 deg. Cent. At this temperature a d.c. potential of about 30V per 0·001in (in this case 4kV) is applied across the barium titanate, the mass being positive and the base negative. The temperature is then raised to 135 deg. to 140 deg. Cent. and held there for half an hour, after which the pick-up is allowed to cool down slowly. The d.c. potential is not removed until the temperature has fallen to about 70 deg. Cent. In the case of the bolted type of pick-up it was necessary to carry out the polarisation on the disc by itself, since the high voltage would cause electrical breakdown between the mass and the central stud. The disc was assembled in the usual way after polarisation with its positive side to the mass.

In order to obtain the frequency response and the sensitivity of these pick-ups, it was decided to have one calibrated and to use this as a standard, with which any other pick-ups could be compared. This work was carried out by the Admiralty Research Laboratory, who used a reciprocity technique to obtain the pick-up response in the range 50 to 10,000 c/s. Their results showed that sensitivity was flat to about 1 dB up to 5000 c/s, and that from 5000 to 10,000 c/s there were one or two small resonances of less than 5 dB, which can probably be ascribed to the method of mounting. Several pick-ups were later compared with this standard by mounting both on a vibration generator and obtaining the relative outputs at various frequencies up to 10 kc/s. It was found that all the pick-ups tested in this way, of both kinds of construction, had similar response curves to the standard one. A typical response curve is shown in Fig. 7.

The output from this form of vibration pick-up should be fed into a cathode follower with high input impedance, and this should be placed as close to the pick-up as convenient. In the case of this machine, the cathode follower is built into the frame and its output is taken to a suitable socket, from which it can be taken to any one of several different kinds of measuring instruments. This point is discussed in the next section.

Evaluation of Vibration Measurements.—The question of the most suitable methods of interpreting the results obtained from this machine is still under consideration; briefly, the possibilities are as follows. The output taken directly from the pick-up gives a measure of the acceleration component of the vibration. Alternatively, if this is not considered to be suitable, a single or double integrating circuit can be used to obtain the velocity or displacement components. The choice depends largely on what effect of vibration is under consideration—such as wear or airborne noise.

Again, having obtained an electrical signal, whether proportional to acceleration, velocity or displacement, several methods of evaluation can be used. The simplest is to take the r.m.s. value of the total output directly as a measure of vibration, but this will, in general, not give all the required information. The most informative method is to subject the signal to a complete spectrum analysis, but to carry this out at each speed and loading condition on a large number of ball bearings would be very tedious and would take far too long. A possible compromise is to carry out an octave analysis—that is, dividing the frequency range into suitable octave bands and evaluating the r.m.s. amplitudes of each band. This can be done by means of an octave filter. If this division is thought to be too coarse, a third-octave analysis is also possible. In addition, there are instruments available commercially which carry out a third-octave analysis automatically, presenting the results in the form of a paper chart.

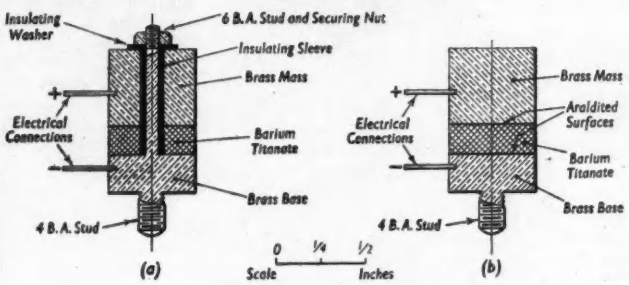


Fig. 6

As can be seen, there are a comparatively large number of methods of evaluating the results of a vibration test and the one to be used must be decided on the merits of each particular case. Further work in progress at the moment is intended to obtain typical results by the various methods and to compare their usefulness in judging the quality of a particular ball bearing.

ACKNOWLEDGMENTS

The author wishes to express his thanks to the Admiralty Research Laboratory at Teddington for its co-operation in the design and calibration of vibration pick-ups. The work described was carried out under Admiralty contract and forms part of the research programme of the Mechanical Engineering Research Board of the Department of Scientific and Industrial Research. The article is published by permission of the Director of Mechanical Engineering Research.

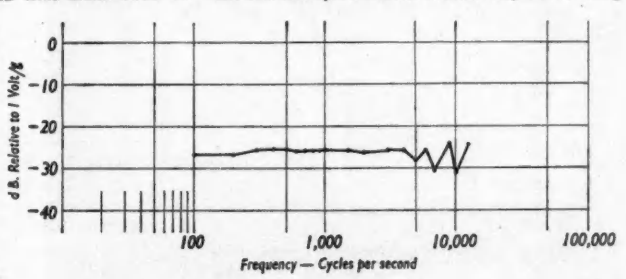


Fig. 7

Mr. H. P. T. Lind

THE death occurred on December 1 of Mr. H. P. T. Lind, the chairman of the contracting firm which bears his name; he was sixty-six and was Danish by birth. Herman Peter Thygesen Lind founded Peter Lind and Co. in 1915, in partnership with the late Mr. A. Ingerslev. He had previously specialised in reinforced concrete construction and the firm specialised in this class of work, in which it is, of course, still very active. The works it has built over the past forty years are numerous and varied; pride of place, however, goes to the Waterloo Bridge over the Thames. Mr. Lind was also chairman of the firm of Tileman and Co., Ltd., which specialises in the construction of reinforced concrete chimneys, and also cement works. He also had chairmanships of various gravel companies and he was chairman of the North Staffordshire Gravels Association. His social connections with various Danish organisations in this country were strong; he was a member of the "Civils" and the "Structurals," and served on the council of the Federation of Civil Engineering Contractors.

Aircraft Materials

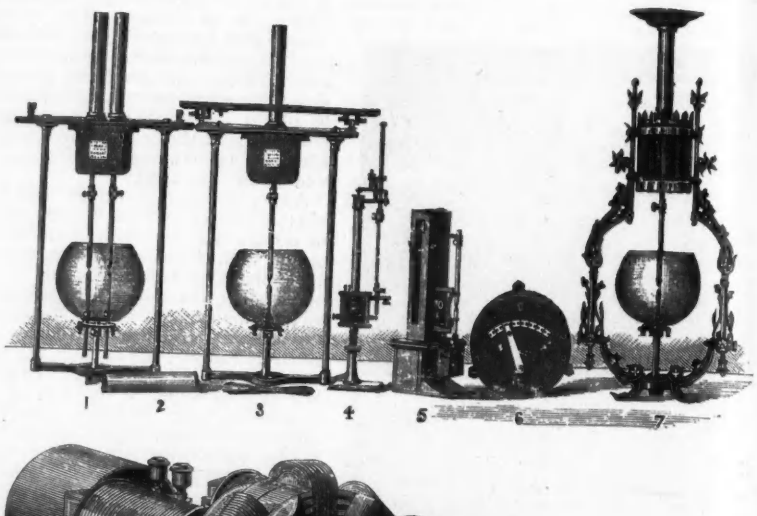
ON December 11, Professor A. J. Murphy addressed the Royal Aeronautical Society on the subject of "Materials for Aircraft Structures Subject to Kinetic Heating." In estimating the working temperatures, he confined himself to flight speeds of Mach 4 or less, and adopted calculated figures for a body of emissivity 0·9 flying in the stratosphere, giving a metal temperature of 370 deg. Cent. This, he pointed out, was lower than most estimates; the originator of the figures, in discussion, suggested that 0·8 might be a more realistic emissivity. Pointing out that it was desirable to make the maximum use of the accumulated experience in the available and convenient light alloys, the speaker discussed their behaviour under prolonged heating. A typical aluminium sheet, 26S, if aged at a temperature greater than 160 deg. Cent., reached a maximum strength and then deteriorated; it was therefore desirable to under-age the new structure. In contrast, sintered aluminium powder showed no change with time at elevated temperatures, and recovered its original properties identically when cooled. It had the relatively high elastic modulus of $11 \cdot 3 \times 10^6$ and ultimate and proof strengths of 25 and 15 tons; compared to alloys of aluminium, it was superior in resistance to fatigue above 250 deg. Cent. and creep above 200 deg. Cent.

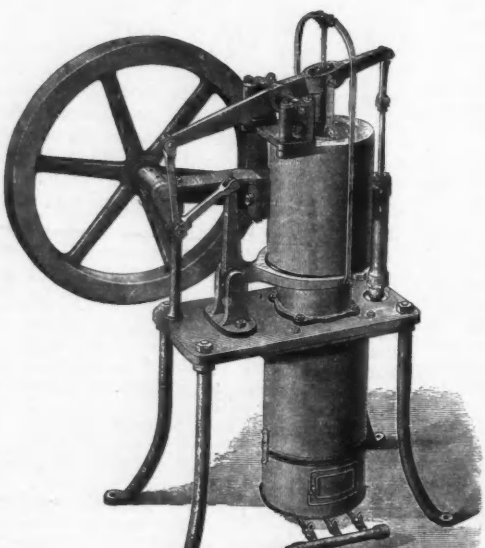
Professor Murphy, discussing the qualities desired in materials, evolved a sensitive criterion of the stresses under heat transfer by dividing stress modulus ($E \times$ coefficient of expansion) by diffusivity; for aluminium alloys this was 380 (less for magnesium), for stainless steel 5000, and for "Nimonic 90" or "Inconel" X 12,210. He drew particular attention to the merits of "Invar" alloyed with about 2 per cent titanium; the addition changed the coefficient of expansion, giving a lower total expansion beyond 300 deg. Cent., but rendered precipitation hardening possible. Thus the material could be worked soft, with an ultimate tensile strength of 40 tons, and subsequently brought up to an ultimate of 87 tons with a proof stress of 74 tons. With a thermal stress modulus one-eighth that of titanium, such an "Invar" would show a stress modulus/diffusivity quotient of 5000. Since precipitation took place at 675 deg. Cent., he did not believe that running at 400 deg. Cent. would have any adverse effect.

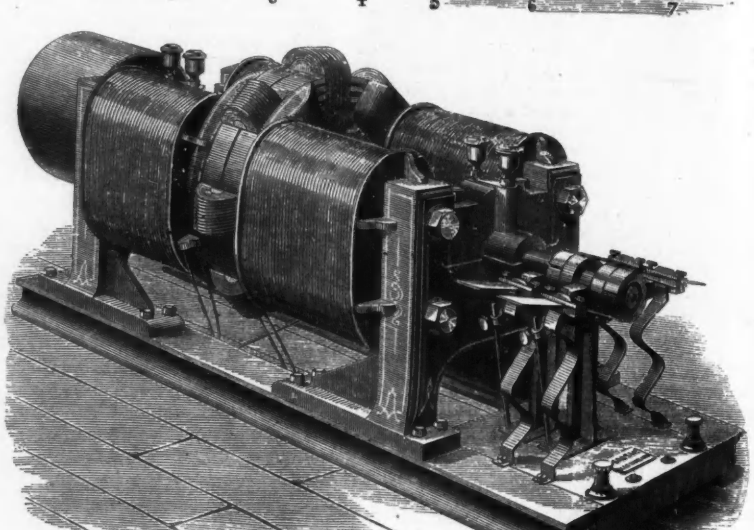
DAMODAR VALLEY DEVELOPMENT.—The Damodar Valley Corporation has published a booklet in which the work of harnessing the Damodar River and the associated developments in the Damodar valley are described. The booklet is called "Eight Years of D.V.C." It gives an illustrated account of the technical and social problems of this river valley project and also explains the organisation of the Corporation itself.

ENGRAVINGS OF 1881

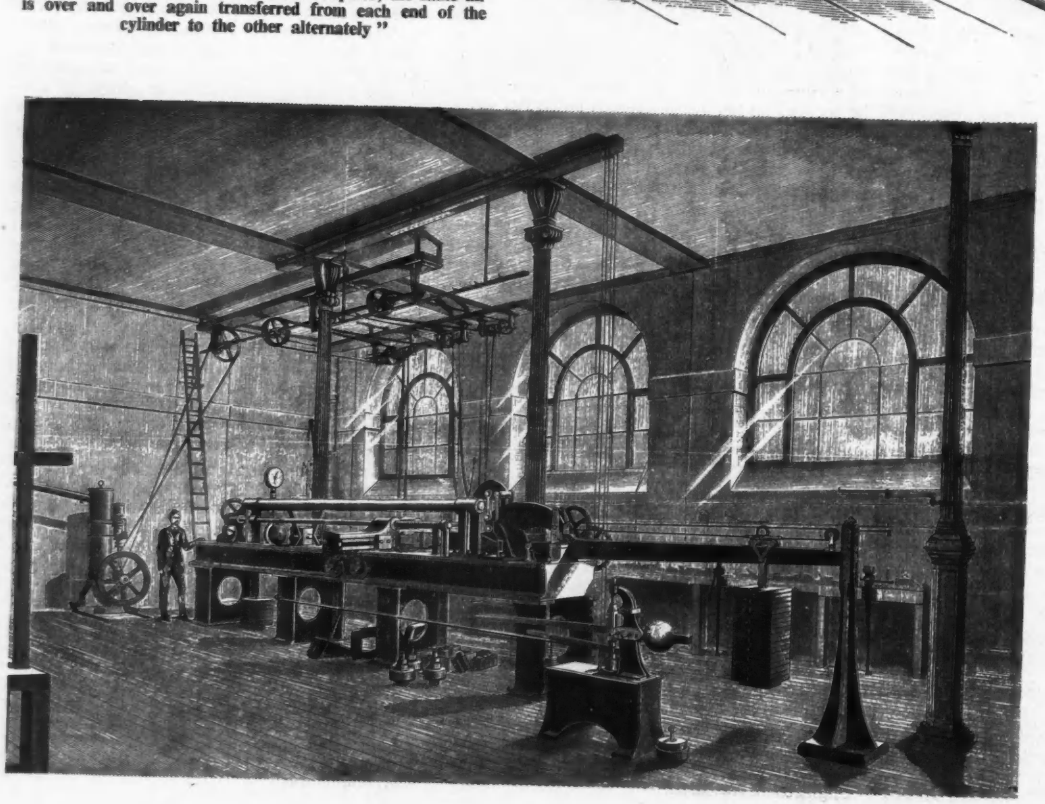
In our issue of January 7, 1881, there appears some account of the introduction of electric lighting to Broadway, New York. The work was done by the Brush Electric Light Company, and the right-hand engraving illustrates the construction of the lamps and also the "dynamo-electric machine requiring 14 horsepower to drive it"







The above engraving, reproduced from our issue of April 15, 1881, illustrates a small hot air engine which was designed by Mr. John Ericsson. The description says that the engine belonged to "that class in which, by the action of a piston which may be termed the 'exchange piston,' working in a cylinder at or near one end of which is the working piston, and at the other end of which is the fireplace, the same air is over and over again transferred from each end of the cylinder to the other alternately"



The left-hand engraving illustrates a testing machine which was installed in the engineering laboratory at University College, London, by Greenwood and Batley, of Leeds. It was designed by Mr. Kennedy, Professor of Engineering at the College, and described in our issue of February 25, 1881. The description explains that the machine "is worked by manual power at present, and closely resembles Mr. Kirkaldy's machine in some of its features. It can exert a maximum strain of 100,000 lb and can either stretch, compress, or bend a specimen to be tested. The strain is applied by hydraulic pressure, and the amount of the strain is measured by a dead weight acting through a system of levers"

LITERATURE

Jane's All the World's Aircraft, 1956–57. LEONARD BRIDGEMAN and JOHN W. R. TAYLOR. Sampson Low, Marston and Co., Ltd., 25, Gilbert Street, London, W.1. Price 84s.

FEW there can be who place each year's *Jane's* on the shelf for reference throughout the year without a prolonged leafing through the pages, both to renew old acquaintance with the "Meteor" night fighters (no weights or performance data available) and the "D.H.110" (no weights or performance data available), and to introduce themselves to the Lockheed "Starfighter," flying in the region of Mach 2·5 in both level and climbing flight ("thickness/chord ratio of 3·4 per cent, leading-edge nose radius of 0·016in and razor-sharp trailing edge.... Maximum loaded weight approximately 15,000 lb"). This year's issue, with 10 per cent more text than last, will not fail to convert a casual inspection into an extended examination.

The aeroplane section, the major part of the volume, includes over 750 illustrations of the machines of twenty-nine countries. Remarkable is the upsurge of interest in short or vertical take-off; projects for "convertiplanes," "flying platforms," jet lift and slipstream deflection are numerous, particularly in France and U.S.A. Also numerous, except in Great Britain, are light private aircraft, in many cases intended for amateur construction. A further category that is conspicuous by its absence in this country is the swept-wing twin-engine military aircraft of near Mach 1 performance; such versatile projects as the S.O. "Vautour" and Yakovlev's "Flashlight" all-weather fighters and attack bombers, or the Douglas "Skywarrior" bomber/minelayer, and its land-based equivalent, have no British equivalent. Some such successor to the "Canberra" must surely be envisaged?

This section inspires one critical thought: on occasions it recalls the record book of cricket—is it worth while recording "the first *all-metal*, *two-seat*, *light*, jet-propelled aircraft to fly," or noting that an "experimental four-seat amphibian flying-boat with submerged (*sic*) engine driving a propeller behind the tail by a drive shaft with cardan joints... was the first aircraft with these features to fly"? Still less welcome is it to read that the F.D.2 "was and still is the first" aircraft to exceed 1000 m.p.h. under F.A.I. observation. It also disappoints by omitting the "Eland"-engined "Convair-Liner."

The aeroplane section has been supplemented by a guided missile sub-section, and it is clear that this has caused the compilers unusual difficulty. In the (short) division devoted to this country, the only evidence for the physical reality of the A.W. "Sea Slug" or the larger "Fireflash" development is that models were displayed in 1955.

Technical interest is strong in the engine section. An item that cannot fail to intrigue is that devoted to Marquardt athodyds; these include supersonic (inclined shock) and subsonic ramjets, and among the latter is a two-dimensional duct for helicopter rotor-tip installation only 2½in deep, 4 lb in weight, and providing 40 lb thrust. *Jane's* may well describe as "completely new" an exhaust nozzle which incorporates a reverse thrust feature and the "ability to trim in flight to an area which will achieve the minimum specific fuel consumption for the turbo-jet engine for a given cruise thrust requirement. This feature alone will more than pay for the added weight of the nozzle (less than 100 lb)."

New in the piston engines section are omissions rather than inclusions—Napier no longer appear, and Rolls-Royce are recorded as having concluded production of reciprocating engines after forty years. As the editor observes, the airship section could now be described as the Goodyear section, the U.S. Navy being the only operator of aerostats.

Sutcliffe's Manual of Belt Conveying. By HAROLD STREETS. W. and R. Chambers, Ltd., 11, Thistle Street, Edinburgh, 2. Price 25s.

THIS is essentially a practical book based upon the extensive experience of the author, who is the technical director of Richard Sutcliffe, Ltd., a firm which has specialised in the design and manufacture of belt conveyors for over fifty years. With the increasing emphasis upon the mechanical handling of materials in recent years belt conveyors have been developed and adapted for handling a greater variety of materials in bulk and package, and at rates far in excess of what was considered possible only a few years ago. It is with these modern developments the book is primarily concerned.

The author first gives a brief history of the belt conveyor and then goes on to describe in practical detail the construction, uses and selection of belts for various duties. Conveyor installations, drives and ancillary equipment are then discussed in some detail, concluding with a chapter on the use and maintenance necessary to obtain trouble-free operation. In practically every case where the author describes the particular application of a belt installation or piece of ancillary equipment he also draws attention to its qualities and, what is possibly more important, its limitations.

The book provides an essentially practical treatise for the engineer who is concerned with the introduction or planning of a belt conveyor installation or with its maintenance and use, rather than a theoretical guide for designers. It also provides for students and those less familiar with belt conveying a clear general explanation of principles as well as the reasons behind different practices in modern conveying installations. For these reasons the book is a welcome addition to the literature available on mechanical handling.

Induction Heating Practice. By D. WARBURTON-BROWN, A.M.I.E.E. Odhams Press, Ltd., Long Acre, London. Price 21s.

THIS book is concerned with the practical side of induction heating rather than with underlying theory, since it is intended to appeal to production engineers, works managers and others concerned with the use of the process. With this readership in mind, the author's approach is that the choice of equipment for any given application will be decided by the size and design of commercially available generators rather than than by purely theoretical considerations. Accordingly, detailed consideration is given to specific kinds of work. The book begins with a short review of the practice of induction heating; the design and use of work coils and inductors; induction soldering and brazing; induction hardening, with many examples such as valves, push-rods, fuel injectors and shackle pins. There are separate chapters on gear hardening and miscellaneous applications, including annealing, forging, the sintering of tool tips and the induction melting of gold. The possibilities of modifying the design of components to facilitate the application of induction heating is discussed briefly, and the final chapter deals with the design of the associated jigs and fixtures which are required to enable induction heating to be used as a production tool.

Elements of Mechanics and Mechanisms. By F. J. CAMM. George Newnes, Ltd., Tower House, Southampton Row, W.C.2. Price 30s.

THIS book is based upon a series of articles published in *Practical Mechanics*, and is stated to be the outcome of requests from teachers and students for the series to be made available in book form. The text of the articles was revised and amplified to provide a comprehensive elementary guide to the laws of motion, friction, mass and momentum; force, energy and power; the lever; the wheel and axle; the gear; the inclined plane; hydraulics; intermittent mechanisms; power transmissions; and other aspects of the subject which form an introduction to machine design. In it the elementary principles of mechanics and mechanisms are dealt with in a concise, simple manner, which will appeal to students and provides them with a useful source of reference. Young designers and draughtsmen will find the large section which has been devoted to descriptions of mechanical movements an interesting supplement to the first principles with which the earlier chapters are concerned. The book is amply illustrated with simple drawings and diagrams and well indexed.

Engineering Science and Calculations, Vol. I. By W. E. FISHER, O.B.E., D.Sc., A.M.I. Mech.E. English Universities Press, Ltd., 102, Newgate Street, London, E.C.1. Price 15s.

VOLUMES I and II of the three under this title have now been added to the General Technical Series. Both scientific and mathematical chapters appear in each book. This volume contains ample material for a first year of study in the Intermediate Courses for the City and Guilds of London examinations, a selection of questions from which follow each chapter. The chapters run in sequence through the first two volumes, and cross references to Vol. II occur, but there is a highly condensed index at the end of Vol. I.

Books Received

Dumpy Level Work. By J. Vose. Cleaver-Hume Press, Ltd., 31, Wright's Lane, Kensington, London, W.8. Price 9s. 6d.

The Use and Welding of Aluminium in Shipbuilding. The Institute of Welding, 29, Park Crescent, London, W.1. Price 32s. 6d.

Friction and Lubrication. By F. P. Bowden and D. Tabor. Methuen and Co., Ltd., 36, Essex Street, London, W.C.2. Price 10s. 6d.

Whitaker's Almanack, 1957. Complete edition. J. Whitaker and Sons, Ltd., 13, Bedford Square, London, W.C.1. Price 18s. 6d.

The Art and Science of Protective Relaying. By C. Russell Mason. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 96s.

Newsprint Mill at Kemsley

No. II—(*Concluded from page* 854, *December* 14)

An expansion and development programme at the Kemsley newsprint mill of the Bowater Paper Corporation, Ltd., has involved the construction of an additional newsprint machine of 60,000 *tons per annum capacity, and a new electric power plant of* 15,000*kW, which incorporates a new coal-handling system and a boiler having a maximum continuous rating of* 450,000 *lb per hour of steam at a pressure of* 1550 *lb per square inch gauge and a temperature of* 925 *deg. Fah.*

CONCURRENT with the mechanical problems of building a new newsprint mill and its auxiliary equipment was the related question of power supplies. To meet the increased demands for electricity which amounted to about 6000kW for No. 6 machine, and approaching a load of 9000kW for the groundwood mill a new power plant was designed. This consisted of a 15,000kW turbine-driven alternator, taking steam at high pressure and temperature from a large-capacity boiler. Having decided upon the electrical power requirements, a technical analysis was made to determine the best thermodynamic solution of the problem of steam supplies. It was found necessary to marry the steam requirements of the Kemsley and Sittingbourne mills and eventually the decision was made to install a back-pressure turbine taking steam at 1550 lb per square inch and 925 deg. Fah. and exhausting into the existing steam system at 350 lb per square inch and 750 deg. Fah. To supply the steam a boiler of 450,000 lb per hour was planned, and arranged with a section to take the turbine steam exhaust for reheating to bring it up to the temperature of the existing medium-pressure system. Some of this steam was to be conveyed by pipeline to the Sittingbourne mill some 2½ miles away so that seventeen old boilers there could be dispensed with. This scheme was estimated to effect a saving of 50,000 tons of coal per annum. Associated with the boiler plant a new coal jetty and conveyor system was planned, together with railborne coal arrangements.

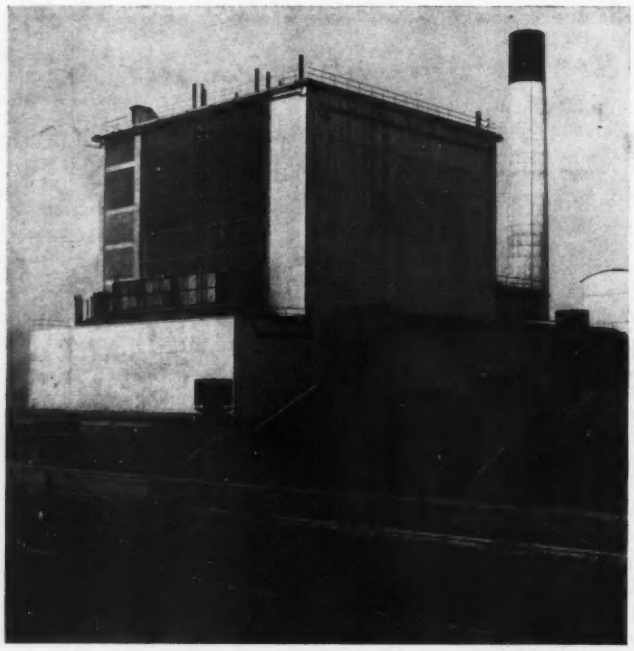
The new deep-water coal jetty, which we illustrate, was built in the Elmley Reach of the River Swale and has two 3½-ton level-luffing grabbing jib cranes, which deliver coal into one of two hoppers. From here the coal passes via vibratory feeders of 100 tons per hour capacity, and a conveyor belt of 150 tons per hour rating, which feeds overhead to a conveyor of the same capacity, which rests on the causeway and terminates at a junction tower. Conveyor No. 3 transfers the coal to the storage area, of a size able to take 120,000 tons of coal, where it is handled by a bulldozer, or on to No. 4 conveyor, rated at 100 tons per hour, which can also receive coal from storage via a vibratory feeder, and which discharges to a Niagara screen. Here oversize coal is deflected to a crusher or bypassed to No. 5 conveyor supplying No. 6 conveyor, of 50 tons per hour capacity, which terminates in a conveyor housing over No. 1 boiler house, and the 100 tons per hour No. 7 conveyor, which delivers fuel to the bunkers for the new boiler. A 25-ton Strachan and Henshaw side discharge wagon tippler handles railborne coal which is drawn from the tippler hopper by vibratory feeders and is fed by a 100-ton per hour conveyor to storage or to the No. 4 conveyor.

The boiler, built by the Stirling Boiler Company, Ltd., and seen under construction in our illustration, is of natural circulation radiant design fitted for pulverised fuel firing and dry ash removal, and having an integral reheater. It has a heating surface of 10,340 square feet, a superheater of 8150 square feet surface area and an economiser of continuous loop pattern, having a tubular heating surface, disposed on three tiers, of 19,150 square feet. The combustion chamber has a volume of 59,000 cubic feet, while the weight of water in the water walls and connections amounts to 120,064 lb hot, the corresponding amount in the economiser being 29,120 lb. Steam pressure and temperature at the superheater outlet is 1550 lb per square inch gauge and 925 deg. Fah. respectively, and the boiler has a maximum continuous rating of 450,000 lb per hour. Exhaust steam from the back-pressure turbine enters the reheater at 370 lb per square inch gauge and 575 deg. Fah., leaves at 350 lb per square inch gauge and 750 deg. Fah., and enters a receiver. This supplies steam to the two Weir's turbo-feed pumps, which exhaust to the feed heaters via the 110 lb per square inch gauge, 520 deg. Fah. steam main. In addition to the turbo-feed pumps there is an electro-feeder driven by a 1120 h.p. motor, and all three pumps, which are of ten-stage ring section design, are rated to deliver 270,000 lb per hour of condensate at 227 deg. Fah. against a discharge pressure of 1940 lb per square inch gauge. Steam consumption ranges from 49,000 lb to 61,000 lb per hour between no load and full load. There are two Weir's feed water heaters and each has a surface of 1000 square feet and raises the temperature of 270,000 lb per hour of feed water from 227 deg. to 327 deg. Fah., at which temperature it enters the economiser. The boiler is housed in a steel-framed structure 142ft high, standing on concrete pile foundations and designed to meet the special requirements of a top-slung boiler. Cladding is generally in 20-gauge troughed aluminium sheeting having an "Alochrome," finish, and there are large areas of patent glazing. There is also a free-standing reinforced concrete chimney 200ft. high.

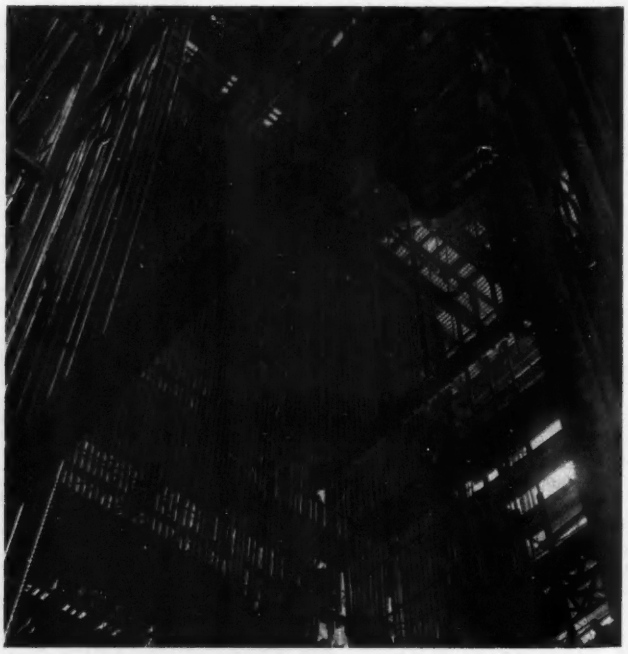
The necessary conditioning chemicals are injected direct to the boiler drum by a shell pump, and, in order to protect the economiser tubes against corrosion, a Weir three-throw reciprocating recirculation pump is installed to withdraw 11,000 lb per hour of chemically conditioned water from the boiler drum at 1625 lb per square inch gauge and 608 deg. Fah., and inject it into the feed line at the economiser inlet. Other pumps include two 600,000 lb per hour, against 120ft head, condensate lift pumps and two 15,000 lb per hour condensate drains tank pumps supplied by Gwynnes Pumps, Ltd. Drysdale and Co., Ltd., has provided two 80,000 lb per hour raw water lift pumps, two 60,000 lb per hour general service pumps having a pumping pressure of 137ft, a discharge pressure in parallel of 217ft, and 354ft in series, and two 190,000 lb per hour condensate return pumps at Sittingbourne.

The feed water for the new boiler consists of condensate from the turbines and paper machines, make-up being supplied to the old low pressure boilers from the new 300,000 lb per hour water softening plant. Weir's deaerating plant, complete with two 10,000 gallons deaerated water storage/surge tanks, can handle 540,000 lb per hour of feed water having a guaranteed oxygen content not exceeding 0·02 c.c. per litre, and raise its temperature from 130 deg. to 227 deg. Fah. There is a high level condensate tank and also a conservator tank, each of 20,000 gallons capacity, and a high level raw water tank to hold 12,000 gallons.

To enable steam to pass direct from the high pressure boiler to the low pressure system, bypassing the new turbine, or to work in parallel with the turbine at loads, Hopkinsons, Ltd.,



Boiler house clad with troughed aluminium sheeting



High-pressure boiler during erection

Unit control panel and unit alarm desk for the high pressure boiler

15MW turbo-alternator, for steam at 1500 lb per square inch and 900 deg. Fah.

has supplied main pressure reducing desuperheating stations "A" and "B." They have a steam inlet pressure and temperature of 1550 lb per square inch gauge and 925 deg. Fah., a control pressure of 350 lb per square inch gauge with an outlet temperature of 600 deg. Fah., and a capacity of 225,000 lb per hour each. Units "A" and "B" operating in parallel consist of electrically operated steam and water isolating valves, Dolly pattern pressure reducing valves and locally mounted panels housing the automatic control equipment and indicating instruments. These stations are under push-button control from the main unit panel.

The main steam drum, which is fusion welded and fitted with steam scrubbers and cyclone separators, has an internal diameter of 5ft 6in and a shell 4 13/16in thick, and is suspended from the overhead steelwork by laminated springs. A spray pattern attemperator is fitted in the steam path between the multi-loop self-draining primary and secondary superheaters, and a similar attemperator is located at the inlet of the reheater section of the boiler. All the primary air passes through two Newton Chambers tubular heaters which can raise the temperature of the air to 550 deg. Fah. The two main air heaters are of Howden Ljungstrom pattern.

Coal from the bunkers is fed, via Simon automatic self-compensating weighers, to four mills and is delivered to sixteen 10in vertical inter-tube burners, each of 2900/5800 lb per hour capacity, installed for opposed vertical firing. For lighting up there are two Hamworthy pressure pumps, two flow pattern heaters, and two 10,000-gallon heated storage tanks to supply the eight 800 lb per hour automatic pressure atomising burners. There are three Keith Blackman sealing air fans, and James Howden and Co., Ltd., has supplied two induced draught and two forced draught fans and four primary air fans, and also two "Centicell" dust collectors. In the dust handling plant, provided by Babcock and Wilcox, Ltd., the dust is collected from hoppers at the two air heaters, two primary air heaters, economiser and chimney and also from twelve points on the "Centicell" dust collectors. The dust is pneumatically fed to one of two hydrovactors and discharged into the dust transfer sump, from which it is pumped by one of two dust pumps to the dust ponds. Two Mather and Platt pumps of 1000 gallons per minute capacity against a head of 245ft supply the necessary water. Boiler ash is collected in a bottom discharge hopper which is emptied through six hydraulically operated gates into road vehicles.

Copes "Flowmatic" feed water control is fitted and Bailey Meters and Controls, Ltd., has supplied a remote manual combustion control system, furnace draught indicator and combustion meter, and a unit control panel in front of which is a unit alarm desk, manufactured by Standard Telephones and Cables, Ltd. The control unit and alarm desk are illustrated.

The English Electric single cylinder, twelve-stage back pressure h.p. turbine, having impulse blading, is designed to take steam at 1500 lb per square inch gauge and 900 deg. Fah., and have a back pressure of 370 lb per square inch gauge. It drives the 15MW, 6·6kV, main alternator at 3000 r.p.m., and both can be seen in our illustration. The power factor at the alternator terminals is 0·8 lagging and the alternator reactance is 15·5 per cent. The stator has a phase current of 1640A, while the excitation current of the rotor at no load normal volts is 103A and 297A at full kVA output normal volts. Rotor excitation voltage at no load normal volts cold is 44V and 184V at full kVA output normal volts hot. The main exciter has a maximum continuous output of 70kW at 200V, the corresponding values for the pilot exciter being 1·6kW and 220V. A centrifugal governor operated through a hydraulic relay is fitted to the turbine and also an emergency governor. There are a 120 gallons per minute main oil pump and two auxiliary pumps, one of 120 gallons and the other of 80 gallons per minute capacity. While the set is being turned by the barring motor the bearings are supplied with lubricating oil by a barring oil flushing pump. Three Serck oil coolers are fitted, a settling tank holding 800 gallons and an Alfa-Laval oil purifier and heater. The switchgear has been provided by the English Electric Company, Ltd., British Thomson-Houston Company, Ltd., Ferguson, Pailin, Ltd., and Contactor Switchgear, Ltd.

Coaling jetty on River Swale showing grab cranes and part of conveyor system

Aiton and Co., Ltd., was responsible for the pipework, lagged by the Darlington Insulation Company, Ltd., in the power station, while the Brightside Engineering Company, Ltd., was concerned with the Kemsley-Sittingbourne pipelines, which are insulated with "Eldorite" finished with aluminium sheeting or "Asbex" roofing felt. These lines consist of an 8in steam line to take 60,000 lb per hour at full load, the pressure and temperature at Kemsley being 350 lb per square inch gauge and 750 deg. Fah., dropping to 150 lb and 612 deg. Fah. at Sittingbourne. The corresponding data for the 20in steam line is 170,000 lb per hour, 110 lb per square inch gauge, and 520 deg. Fah., and 75 lb and 470 deg. Fah. There is also an 8in condensate return line capable of handling 190,000 lb per hour of condensate at 180 deg. Fah. and 75 lb per square inch gauge.

Other work involved in the general scheme of development included the transfer of No. 4 and No. 7 turbo-alternators, with The General Electric Company, Ltd., being responsible for modifications to the sets.

The overall planning and co-ordination of design was undertaken by the engineering division of the Bowater Paper Corporation, Ltd., and the engineering consultants for the power plant and coal handling scheme were Ewbank and Partners, Ltd. Messrs. Farmer and Dark were the architectural consultants, Sir Alexander Gibb and Partners were the consulting engineers for the coaling jetty, and Messrs. Rendel, Palmer and Tritton acted as consultants for the piling. The following industrial firms were involved in addition to those specifically mentioned.

Higgs and Hill, Ltd., and J. Mowlem and Co., Ltd., contractors; Redpath Brown, building steelwork; Allen West and Co., Ltd., starters; Dewrance and Co., Ltd., gauges and safety valves; Arens Controls, Ltd., control gear; George Kent, Ltd., gas analysis recorders; Lockers (Engineering), Ltd., and Niagara Screens, Ltd., vibrating feeders; Fluidrive Engineering Company, Ltd., couplings; Worthington Simpson, Ltd., Broadwell Engineering Company, Ltd., pumps; William Kenyon, Ltd., boiler insulation; British Thomson-Houston, Ltd., motors; Braithwaite and Co., Ltd., tanks; Thomas Ward and Co., Ltd., coal moving equipment; Enfield Cables, Ltd., cables; Johnson and Phillips, Ltd., Gresham Transformers, Ltd., transformers; Cementation Company, Ltd., bored piling; William Briggs, Ltd., roofing; Williams and Williams, Ltd., metal windows; Kiers, Ltd., chimney; Mather and Platt, Ltd., pumps, fire doors; Colt Ventilation, Ltd., roof vents; W. H. Heywood, Ltd., patent glazing; Carter-Horsley, aluminium sheeting; The Walmsley (Bury) Group, Ltd., paper machine; Millspaugh, Ltd., suction rolls; Masson Scott Company, Ltd., broke plant; Sturtevant Engineering Company, Ltd., air conditioning; Watford Engineering Works, Ltd., decker thickeners; Porn and Dunwoody, Ltd., lift.

CENTRAL ELECTRICITY AUTHORITY'S NUCLEAR POWER STATION SCHEMES

Fig. 1—Artist's impression of Bradwell nuclear power station

Fig. 2—Model of Bradwell nuclear power station

Fig. 3—Artist's impression of Berkeley nuclear power station

Fig. 4—Model of reactor unit at Berkeley nuclear power station

300MW Nuclear Power Stations for Great Britain

Contracts have been placed for the construction of three nuclear power stations in Great Britain ; one at Bradwell, Essex, another at Berkeley, Goucestershire, and a third in Scotland. They are to have net outputs of 300MW, 275MW, and 300MW respectively, from two gas-cooled, natural-uranium-fuelled, graphite-moderated reactors, which, being specifically designed for power production, are improved versions of those at Calder Hall. Some details of the contracts are given here. The stations are due to be completed in 1961.

LAST week it was announced that contracts had been placed for the first three nuclear power stations to be built for commercial operation in Great Britain. Two of the stations are for the Central Electricity Authority : one, at Bradwell, Essex, will have a net output of 300MW and will be built by the Nuclear Power Plant Company, Ltd.; the other at Berkeley, Gloucestershire, will have a net output of 275MW and will be built by the A.E.I. - John Thompson Nuclear Energy Company, Ltd. The increased outputs, compared with the original estimates of 100MW to 200MW, are to be obtained within the site facilities already approved by the Minister of Fuel and Power. The Central Electricity Authority states that the two contracts, for the complete power stations in each case, have been awarded subject to clearance of outstanding technical and contractual matters, and that site work is to start early next year, several months in advance of the time originally contemplated.

The third nuclear power station is to be built, for the South of Scotland Electricity Board, by the G.E.C. - Simon-Carves Atomic Energy Group. This station is to have an installed capacity of 360MW and a guaranteed capacity sent out to the grid of 300MW, rising to 320MW.

Last month the Central Electricity Authority announced that, subject to the requisite planning permission and approval by the Minister of Fuel and Power, it was proposed to build the third C.E.A. nuclear power station in Somerset. The Authority is in negotiation with the English Electric - Babcock and Wilcox - Taylor Woodrow group of companies and, if satisfactory agreement is reached, it is intended to proceed with construction at this site as soon as possible after planning approval and consent for the project is obtained (Fig. 8).

The Central Electricity Authority states that the electrical output capacity of the first three C.E.A stations will aggregate some 850MW ; the capital investment will not be less than £120 million.

It is not possible, states the Central Electricity Authority, to forecast with certainty either the cost per kilowatt of the Authority's nuclear power stations or, in particular, the price per unit at which electricity will be delivered from them to the national grid. It is clear, however, that the capital cost will not be less than two and a half to three times that of a comparable coal or oil-burning station and that nuclear generation costs, initially, will probably be higher than that from the Authority's advanced types of thermal plant. The hope and expectation is that construction costs of future nuclear power stations will progressively be reduced and that when more experience has been gained on such important factors as the working life of the reactors, the cost and life of the fuel, then nuclear will become competitive with thermal generation and may even be cheaper. It is with this broad objective in view that the Authority is proceeding with this initial pioneering development.

The Scottish Nuclear Power Station

The Scottish nuclear power station has been designed by the G.E.C. - Simon-Carves Atomic Energy Group. The General Electric Company, Ltd., as main contractor, is to be responsible for the whole project. An artist's impression of the completed station is reproduced in Fig. 5.

Power will be derived from the heat generated in two gas-cooled, graphite-moderated nuclear reactors (Fig. 6) containing natural uranium fuel. The generating capacity of the station will be 360MW and the total output of electrical power is guaranteed to be not less than 300MW, rising to 320MW, which will be available to be fed into the national grid.

Each reactor with its eight steam-raising units will weigh about 70,000 tons, the whole structures being supported on reinforced concrete rafts. The erection programme will be greatly assisted by a specially built "Goliath" crane (Fig. 7) of 200ft span, straddling the construction site, and capable of lifting up to 300 tons at a time.

Associated with the G.E.C. and Simon-Carves, Ltd., in this contract are the Motherwell Bridge and Engineering Company, Ltd., who will fabricate the pressure vessels, and John Mowlem (Scotland), Ltd., who will be the civil contractor.

The cylindrical core of each reactor, 28ft high and 50ft in diameter, will be built up of 2000 tons of graphite blocks containing vertical channels for the fuel elements and control rods. Each of the 3288 fuel channels will contain ten individual fuel elements, each about 2ft long, stacked in a vertical column. The element consists of a bar of natural uranium metal sealed in a magnesium alloy finned can. The total charge of uranium in the two reactors will be 500 tons.

The reactor core will rest on a fabricated grid made of steel plates. Around the sides and top of the core will be an inner steel shell (Fig. 6)

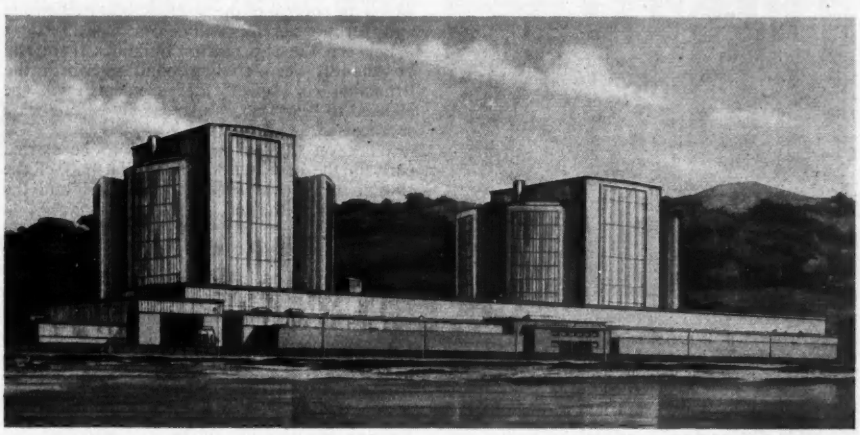


Fig. 5—Artist's impression of the complete nuclear power station to be built by the G.E.C. - Simon-Carves Atomic Energy Group for the South of Scotland Electricity Board

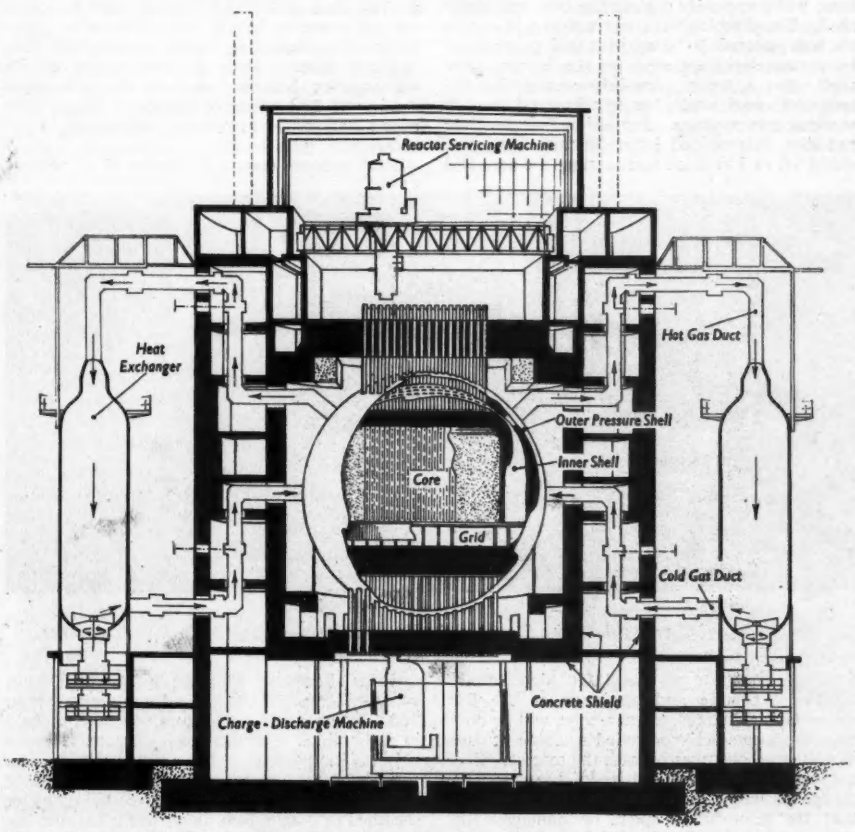


Fig. 6—Diagram of the G.E.C. - Simon-Carves design of nuclear reactor, showing the direction of gas flow through the reactor core and heat exchanger

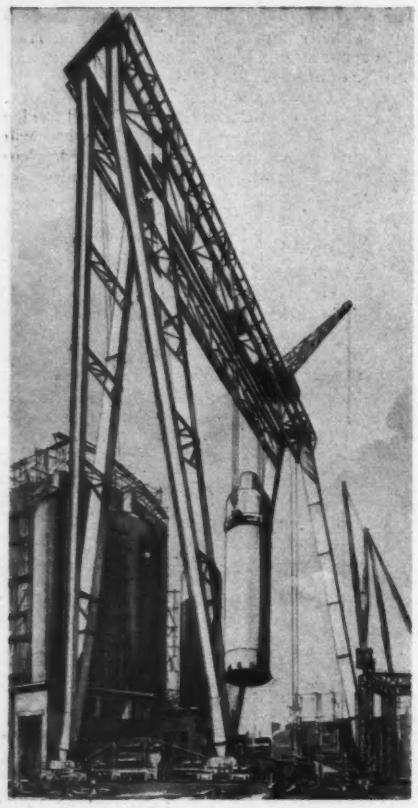


Fig. 7—Artist's impression of the G.E.C.-Simon-Carves design of nuclear power station under construction, showing the 300-ton "Goliath" crane, with a span of 200 feet, lifting a complete prefabricated heat exchanger shell into position

made of relatively thin steel plate. A 70ft diameter spherical pressure vessel, welded from 3in thick steel plate and weighing nearly 1000 tons, will completely enclose the core and inner shell. The double-shell construction will enable the best materials to be used for each purpose—a temperature-resistant steel for the hotter, inner shell, and a tough, non-brittle steel for the spherical vessel which has to withstand the full working gas pressure. Protection from nuclear radiation is provided by a concrete biological shield 9ft to 10ft thick surrounding the core and

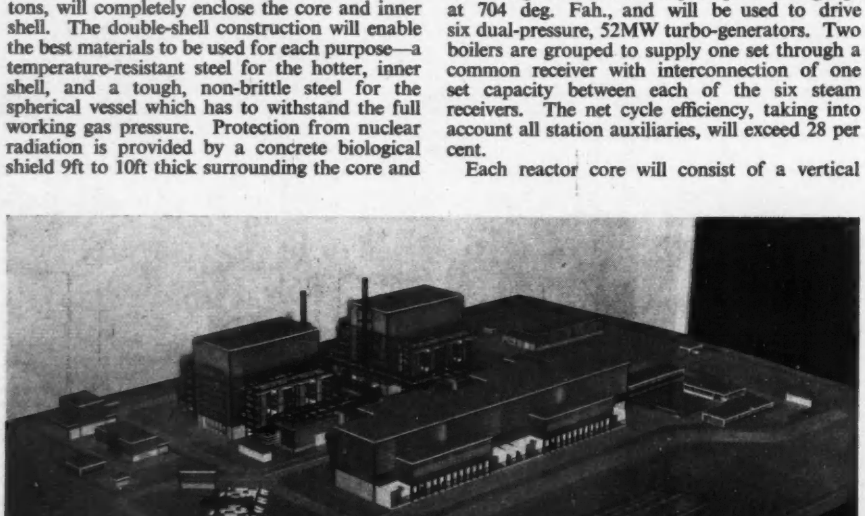


Fig. 8—Model of proposed English Electric-Babcock and Wilcox-Taylor Woodrow nuclear power station for Somerset

forming one face of the 180ft high reactor building. Charge and discharge of the fuel elements in a channel, ten at a time, will be done by a single remotely controlled machine situated in a shielded chamber beneath the reactor. Since the station is intended for base-load working, the charge/discharge machine will be designed so that the removal of spent or damaged fuel elements and the charging of fresh fuel can be carried out while the reactor is on load and under pressure. Charging and discharging will be controlled from a room in the reactor building where the sequence of operations can be viewed on closed-circuit television screens.

The coolant, carbon dioxide, will be circulated at a pressure of 150 lb per square inch. Gas will pass upwards through the fuel channels in the reactor core, and then to the steam-raising towers. There will be eight of these towers, radially disposed in pairs round each reactor. Steam will be generated at two pressures, 585 lb per square inch gauge (at 700 deg. Fah.) and 155 lb per square inch gauge (at 670 deg. Fah.). The tubes in the steam-raising towers will be finned to provide an extended surface. In the base of each steam raiser will be an electrically driven 2200 h.p. blower. The gas temperature at the reactor inlet will be about 392 deg. Fah. and, at the outlet about 752 deg. Fah.

Steam will be piped from the steam-raising units over a bridge to the 700ft long turbine hall containing six 60MW dual-pressure, hydrogen-cooled turbo-generator sets. Besides the ancillary feed heating and condensing plant, the turbine hall will also house the main control room in which the control of the reactors, heat exchangers and turbo-generators will be centralised.

Between the two reactor buildings there will be an 18ft deep cooling pond in which the irradiated or spent fuel elements will be allowed to "cool-off" radioactively before being reprocessed.

Work on the site is expected to be started early in the new year, and the first half of the station to be completed early in 1961 and the second half by the end of 1961.

Bradwell Nuclear Power Station

This station at Bradwell-on-Sea, Essex, will occupy part of a site of approximately 142 acres and when completed will have an output of 300MW s.o. The plant will consist of two natural-uranium, CO_2-gas-cooled, graphite-moderated reactors supplying heat to twelve boiler units. Six boilers will be associated with each reactor and will be placed in two groups of three on opposite sides of the reactor to form one complete unit. Steam from the boilers will be at two pressures, i.e. 755 lb per square inch gauge at 704 deg. Fah. and 195 lb per square inch gauge at 704 deg. Fah., and will be used to drive six dual-pressure, 52MW turbo-generators. Two boilers are grouped to supply one set through a common receiver with interconnection of one set capacity between each of the six steam receivers. The net cycle efficiency, taking into account all station auxiliaries, will exceed 28 per cent.

Each reactor core will consist of a vertical cylinder about 45ft diameter by 31ft high, built up from graphite blocks and containing about 2600 fuel channels. This core will be contained in a 3in thick spherical steel pressure vessel of about 67ft diameter. The reactor will be surrounded by a concrete biological shield about 8ft thick. Uranium rods just over 1in diameter sheathed in magnesium alloy, will constitute the fuel elements.

Carbon dioxide gas at a pressure of 130 lb per square inch will transfer the heat produced in each reactor to its six associated boiler units via 5ft diameter ducts. Six variable-speed, axial-flow blowers, each connected to the outlet of a boiler, will discharge the gas into the reactor vessel. Three 20MW variable-speed turbo-generators, one being standby, are to be used for supplying power to the blower drives, which are standard a.c. induction motors.

The six main turbines will run at 3000 r.p.m. and will be dual-pressure machines having twin exhausts, the back pressure being 0·54 lb per square inch. They will drive standard hydrogen-cooled alternators generating at 11·8kV, feeding into generator transformers with a ratio of 11·8/132kV and will be switched at 132kV. Two station transformers and six unit transformers will be provided. Circulating water will be provided from the River Blackwater and, to prevent recirculation, a baffle wall will be built at the intake, the c.w. intake being on the river side of the wall with the discharge on the shore side of the wall. The longitudinal centre line of the turbine house runs parallel with the centre line passing through the two reactors.

The relative siting of the reactors, cooling pond and turbine house form a combination which provides for the most economical siting and speedy erection procedure. A "Goliath" crane with a height of 140ft, a span of 167ft and a capacity of 200 tons, will facilitate erection. Besides the normal services such as workshops, offices, stores and canteens, there will be the additional services housed in the reactor building or in ancillary buildings for decontamination, fuel store, change rooms, laundries, effluent treatment, health physics laboratories, &c., and solid waste disposal area. The general appearance of the station can be seen from Figs. 1 and 2 on page 890.

The control of the station will be from one central control room in which will be housed the usual electrical equipment, reactor and boiler control board, and turbo-generator control. From this point it will be possible to monitor the whole of the plant and make all essential adjustments necessary for smooth and efficient operation of the station.

It is intended to refuel the reactors on load, a small number of fuel channels being replenished at intervals of a day or so. The irradiated fuel which is removed from the reactors will be stored on site in a cooling pond for several months before being collected by the U.K.A.E.A., and taken to one of their chemical factories where the plutonium and fission products will be extracted.

Berkeley Nuclear Power Station

This station at Berkeley, Gloucestershire, will occupy part of a site of about 96 acres, and when completed will have an output of 275MW s.o. The installation will consist of two natural-uranium, CO_2-gas-cooled, graphite-moderated reactors supplying heat to sixteen boiler units, eight boilers being associated with each reactor and grouped round it to form a complete unit.

Each boiler unit will be contained in a cylindrical steel pressure shell about 70ft high by 17ft 6in diameter, and will raise steam at two pressures, namely, 306 lb and 62 lb per square inch gauge. Both h.p. and l.p. steam will be superheated to 612 deg. Fah. Steam from the boiler units will be used to drive four dual pressure turbo-generators of rather more than 80MW capacity.

The core of each reactor will consist of a vertical cylinder about 48ft diameter by 30ft high, built up from graphite blocks and containing about 3000 vertical fuel channels. This core will be contained in a 3in thick cylindrical steel pressure vessel about 50ft diameter by 80ft high. The reactor will be surrounded by thermal shielding of 4in steel plate and a concrete biological shield about 8ft thick. The fuel elements will be made up of uranium rods just over 1in diameter, sheathed in magnesium alloy.

Carbon-dioxide gas at a pressure of 125 lb per square inch will transfer the heat produced in each reactor to its eight associated boiler units through 5ft diameter ducts. Eight variable-speed, axial-flow blowers driven by a.c. induction motors (each of more than 3000 h.p.) through variable speed hydraulic couplings, will be

connected to the outlet of each boiler, and will discharge the gas into the reactor vessel. The four turbo-generators will incorporate 3000 r.p.m. close-coupled, tandem-compound, mixed-pressure, impulse turbines taking steam at the two pressures generated by the boilers. They will have triple exhausts designed for a back pressure of 0·43 lb per square inch. The generators will be hydrogen-cooled and will generate at 11·8kV. They will feed 11·8/132kV transformers, and switching will be at 132kV. Two station transformers and four unit transformers will be installed.

Circulating water will be provided from the River Severn and to prevent recirculation a baffle wall will be built at the intake, the c.w. intake being on the river side of the wall with the discharge on the shore side of the wall. The longitudinal centre line of the turbine house runs parallel with the centre line passing through the two reactors. The relative positioning of the reactors, cooling pond and turbine house is designed to give the most economical siting and to facilitate erection procedure. In addition to the normal services, such as workshops, offices, stores and canteens, there will be the additional services housed in the reactor building or in ancillary buildings for decontamination, fuel store, change rooms, laundries, effluent treatment, health physics laboratories, and solid active waste disposal area. An artist's impression and a model of the station are illustrated on page 890 (Figs 3 and 4).

The control of the station will be from one central control room in which will be housed the usual electrical equipment, reactor and boiler control board, and turbo-generator control.

Arrangements for refuelling on load, and for handling of irradiated fuel elements in preparation for processing by the U.K. Atomic Energy Authority will be generally similar to those at the Bradwell station.

In the Berkeley nuclear power station the manufacture and installation of the reactor vessels, the 4in thermal shielding, the gas-cooling circuits and the heat exchanger towers, will be carried out by John Thompson, Ltd. The turbo-generators will be the responsibility of Metropolitan-Vickers Electrical Company, Ltd. The gas circulators, reactor-control-rod actuators (150 per reactor), generator transformers, switchgear, rectifiers and auxiliary motors will be supplied by The British Thomson-Houston Company, Ltd.

Central Engineering Establishment of the National Coal Board

The Central Engineering Establishment of the National Coal Board at Bretby is designed to provide an organisation for the development of new coalmining machines, equipment and techniques, and to improve existing methods and machines. Although the establishment is not yet fully completed and equipped, a considerable amount of interesting development work is already in hand and projected.

WE recently accepted an invitation from the National Coal Board to visit the Central Engineering Establishment at Bretby, in South Derbyshire, which has now been in operation for just over a year. The decision to set up this establishment was made in 1952, after it had been apparent for some time that the Board urgently needed a centre where work on the improvement of existing coalmining equipment could be carried out, new machines could be developed, and new techniques tried out. Up to that time practically all development of mining machinery had been primarily the concern of manufacturers, who, with the heavy demands on their productive capacity for existing equipment, had few facilities available for development work. Further, it was difficult to try out new equipment, materials and methods under controlled conditions to ascertain their full value; and in this connection it was desirable that standard testing procedures and specifications of performance for mining equipment should be developed.

The establishment has been organised with the main purpose of accelerating development and testing in the engineering field, and to assist mining engineers with their problems. It will not undertake the manufacture of machines or equipment in quantities, but will only take them to the prototype stage and try them out in order to stimulate the introduction of new and improved machines. As it is not equipped for the construction of complete machines, a substantial amount of the plant manufactured in connection with the establishment's development work will be carried out by outside industrial firms, who will work in co-operation with, and under the direction of, specialist engineers. In addition to developing schemes evolved from within the establishment, it is taking up suggestions from people in the field, developments under the Awards Inventions Scheme, and ideas from other sources considered worthy of development.

The objectives of the establishment can be summarised as follows :—

(i) To develop existing equipment and to design and produce prototypes of new equipment and components.

(ii) To prepare technical specifications and designs of new machines enabling alternative sources of manufacture to be exploited.

(iii) To encourage British manufacturers of mining machinery to speed up development and the introduction of new techniques.

(iv) To prove equipment developed under the development programme and equipment from outside sources.

(v) To evolve standards and methods of acceptance and testing to be used by the Board.

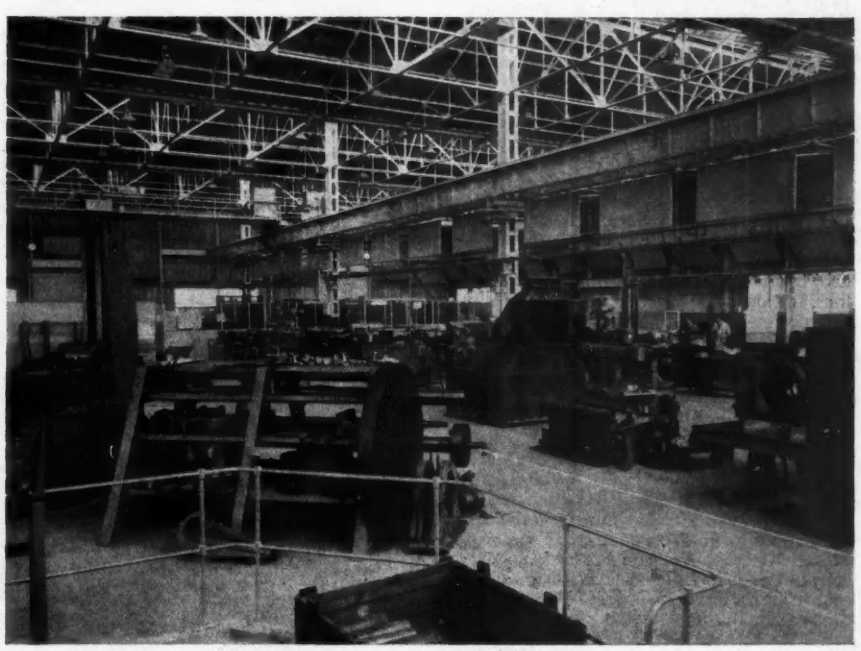
(vi) To carry out acceptance trials of equipment in the pre-production and production stages.

Initially the establishment has been set up on a site of some 20 acres, and its present buildings include offices, two laboratories and a workshop. For future extensions an additional 30 acres of land is available, and there is also at present under construction at the nearby Swadlincote Colliery a rail track some 1½ miles long, with suitable gradients and curves for testing locomotives, mine cars, wagons and various forms of track, and rail fastenings. In the area adjoining this track inclines have been built for testing conveyors, and rigs are to be installed for site testing mine car couplings. A tower is also to be constructed to supplement investigations now being carried out in the laboratories on the use of undrawn nylon ropes for overwind arresting purposes.

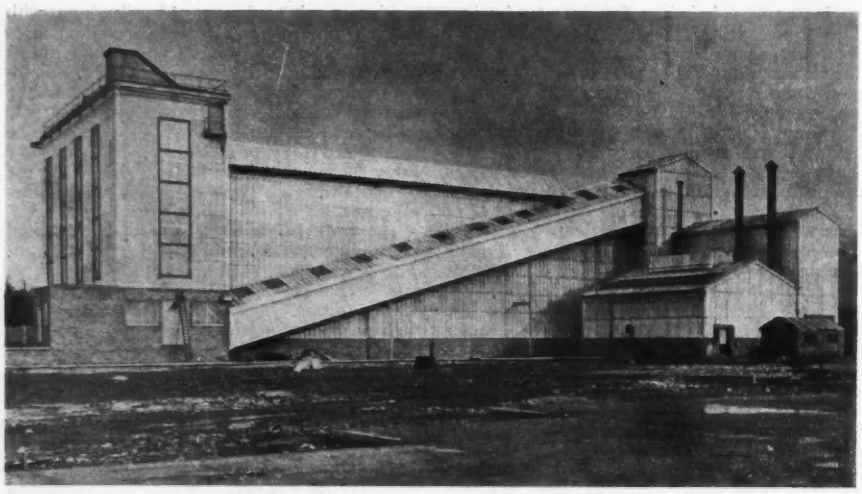
The work of the establishment is organised under six main departments primarily concerned with development engineering, projects, proving and acceptance, workshops, special projects, and administration. The development department with a specialist engineering background is concerned with the design and development of electrical and mechanical equipment and the preparation of specifications of prototype machines. It also prepares specifications to guide projects through development stages, and specifications with the necessary drawings for firms entrusted with the manufacture of equipment for development. When such equipment has completed its development trials test specifications will then be prepared. This department is also responsible for directing development trials in the laboratory and in the field, and it provides an engineering advisory service for the investigation of problems on site.

The project department is engaged in the appraisal of proposed projects as suitable for engineering development, the formulation of technical specifications and preparation of designs, and it prepares and periodically revises the development programme of the establishment. The design and drawing-offices come under the control of this department, which is also responsible for providing technical information services. The special projects department is concerned with developments in specialised or non-traditional fields, including coal preparation, the hydraulic transport of coal and some aspects of mine ventilation. It co-operates with other branches of the establishment in work on power stowing and pumping. As much of the work of this section involves handling hundreds of tons of coal, such projects can be carried out only at collieries, and the department works, therefore, in co-operation with the various production departments of the Coal Board.

The primary function of the proving and acceptance department is to ensure that the machines, materials and equipment used by the Coal Board are of such quality as to give satisfactory service. This is achieved by carrying out acceptance and proving trials, which may be preceded by first-stage trials of prototype



Machine bay of the main workshop building



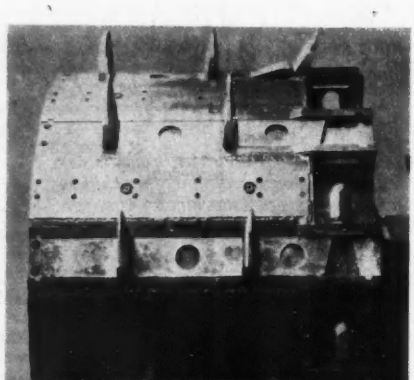
Rear of No. 2 laboratory with boiler house and coal conveyor arranged for delivery to boiler bunker or to equipment in laboratory

equipment. It is not the function of the establishment to conduct routine acceptance trials, but to confine its attention to type testing with one or two special tests, including conveyor belt approval tests, tests on large wire ropes, and tests on roof supports, involving the use of special plant.

The workshop, one corner of which is shown in the illustration on page 893, is equipped to provide general engineering facilities for the establishment and manufacture of prototype equipments. This workshop is well equipped with a comprehensive range of machine tools and incorporates shops for blacksmiths, welders, sheet metal work, and carpenters. It is not generally concerned with the manufacture of large prototype machines, for which orders are placed with specialist firms, but it carries out any modifications and additions to such machines which are required when they are undergoing development trials at the establishment. Smaller components and many of the special test rigs used in development work are made in these workshops, as well as full-scale mock-ups in wood and sheet metal of new machines. These full-scale models provide a valuable three-dimensional basis to assist development and design prior to the manufacture of actual prototypes.

One of the two engineering laboratories is equipped with facilities for testing such things as props, chocks, roof supports, arches, car couplings, conveyor belts and prototype machines. Amongst the equipment in this laboratory is a recently installed pit prop testing machine capable of exerting a compressive force of 360 tons. It is essentially a hydraulic press with a fabricated frame in the form of a continuous open link, to take props up to 8ft long between the table and a hydraulic ram in the head. This ram has a stroke of 18in and provision for rotating its glands during a test enables an accuracy of load measurement to within 1 per cent of the actual load applied. The machine was made by Chatwood-Milner, Ltd., and has two ranges of 0 to 120 tons and 0 to 360 tons, the loads and "yields" being automatically recorded on the control panel.

A roof bar testing rig has a frame consisting of an upper and lower box section built up of channels and plates and held apart by twenty 1¼in diameter screwed rods. The bars to be tested are clamped by a jack against the top box section and they are loaded by a hydraulic ram at up to 18 tons. The load is measured by a strain gauge load cell with a self-balancing bridge load indicator, and deflection measurements are taken at fixed points along the bar or bars under load. The number of special rigs which have been developed for tests on conveyor belts in this laboratory include friction rigs for comparing the driving properties of belts ; holing equipments to simulate the piercing effect of materials carried by the belts ; and specimen flexing rigs. A large open area adjoining the building provides space for the erection and



Anderton drum with end locked coal picks and water spray nozzles

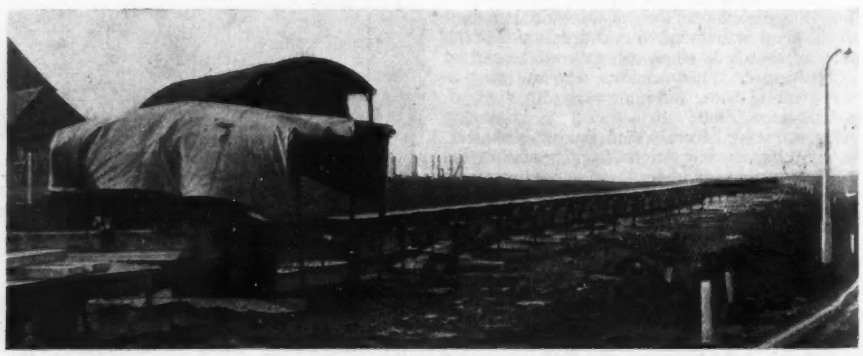
running of complete conveyor installations, trackless machines and similar equipment.

The other laboratory, which is shown in an illustration on this page, provides a clear floor area of some 160ft by 80ft and is used in the development and testing of large equipment such as is used for the handling, cleaning, sizing, drying and transportation of coals. A boiler plant is situated on one side of the building and the conveyor belt which elevates the fuel to the overhead bunker of this plant is also used to provide an overhead feed of coal to the laboratory when large-scale tests are in progress. The coal is fed on to a belt situated near the 50ft eaves level at one end of the building, and a tripper gear can be set to discharge the coal at any required point.

One of the developments shown in this laboratory at the time of our visit was a 12in slurry cyclone which was originated in the North-Western Division of the Board. Its original purpose was to save labour by eliminating the need for manual regulation of the slurry feed to washed fines shakers. A problem was to design a cyclone to operate satisfactorily with a rather sticky and viscous feed delivered at a relatively low pressure. The first installation, at Bank Hall Colliery in January, 1955, was a complete success, and the cyclones gave a properly thickened feed at all times without attention. The cyclones, by improving the recovery of fine coal, made it possible to work the water clarification plant only during the washing shift, where previously the plant had to work an additional shift whilst the washery itself was shut down. This improvement resulted in a financial gain of about £100 per day, and now over a hundred of the 12in slurry cyclones have been distributed for installation at collieries. Following the successful introduction of this cyclone for low pressure operation, it was decided to embark on a programme of cyclone development on broader lines and a battery of 6in cyclones is now working under test conditions.

A prototype blow-off timer for vacuum filters was also shown. This equipment has been developed because the efficiency of vacuum filters for treating coal slurries is often impaired by a failure to obtain a clean discharge of the mat of filter cake. If the cake is at all sticky, removal of the filter cake may be incomplete, whether an air blast or strings are used for cake removal. Normally, when using an air blast for cake discharge, the blast gradually builds up from a minimum when the rotary ports begin to open, increasing to a maximum when the ports are aligned, and gradually decreasing as the ports close. In the initial stage, when the ports start to open, the weak air blast may crack the filter cake or blow off small areas of cake, thereby creating paths of low resistance so that the subsequent stronger air blast passes through such weak places, leaving the bulk of the cake adhering to the drum. The new timing device employs an auxiliary valve to open almost instantaneously when the air blast ports of the filter are substantially fully open, the idea being that the sudden fierce blast will ensure a clean cake discharge. The new device is so designed that it can readily be fitted to existing vacuum filters of most patterns.

A number of interesting equipments are under development in connection with coal cutting, power loading and tunnelling at the establishment. Experiments are being carried out with a new type of drum for use with conventional Anderton machines, with the object of introducing an improved water spray device for the suppression of dust at the coal face and a new kind of pick locking arrangement. In it water is fed under pressure through a special rotary seal to nozzles on the outside periphery of the drum and a cut-off device is arranged in such a



Conveyor on test with intermediate troughed driving pulleys

way that water is sprayed only on the picks in contact with the coal face. The picks with individual locking means on the drum have been replaced by picks which slide freely into dovetail grooves in the drum, where they are spaced by distance bars, as illustrated on page 894. The groups of picks and spacers in each dovetailed groove are locked by a wedge block fitted at one end and tightened by a single nut. For thin seam working an angled jib cutter is being developed in which a number of conventional cutter chains and jibs are to be mounted on a standard coal cutter in such a way that the coal cut by the picks will be carried on to a face conveyor without interference, in an attempt to improve the gumming characteristics. Its three jibs are to be arranged to extract completely a seam of approximately 19in thickness. The top jib is to be mounted on a standard overcut coal cutter in the conventional manner, with the two lower jibs mounted on a bracket attached to the coal cutter body.

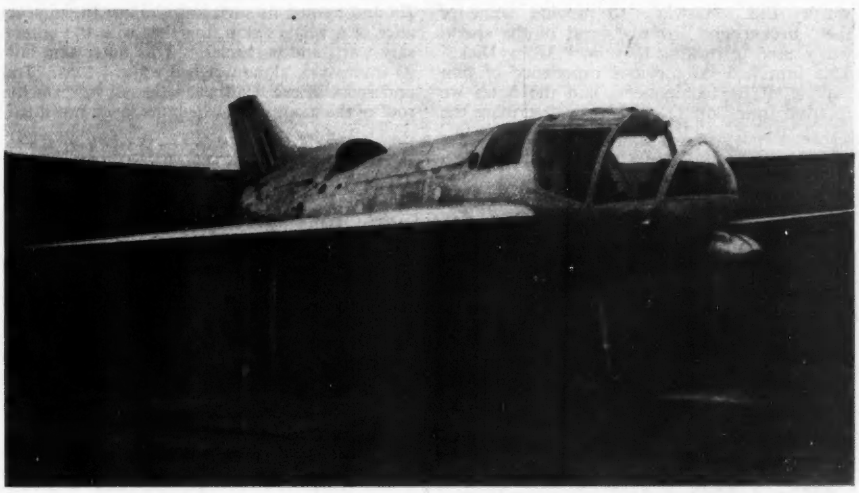
A thin seam buttock machine under development is intended for use on longwall faces in seams from 17in to 24in thick, and it will operate within the buttock, the cut coal being carried by the cutter chains on to an adjacent face conveyor. In this machine a standard overcut coal cutter is used on the basic unit with a new arrangement of jibs mounted across the front of the machine to cut the coal and at the same time carry the cuttings without interference on to the face conveyor. Propulsion is by a combination of hydraulic jacks adapted to react against the floor and roof with horizontal hydraulic rams thrusting on the prop jacks. A vertical drum wide-buttock machine also being developed is intended to provide an equipment which will cut coal two-directionally on a wider buttock than has been previously attempted and is for use in medium thickness seams. It is hoped that it will be possible for this machine to cut its own stable. The present investigation uses the vertical drum principle on a swinging arm, cutting the coal with a shearing action outwards from the face. The coal is conveyed away from the machine by a new form of short-face conveyor with a totally enclosed drive. A roof support system particularly related to this kind of machine will be developed and the machine will be advanced by a walking jack mechanism. Percussive coal ploughing equipments, based upon the designs initiated at the Mining Research Establishment, are being developed for thin seam working, and at the same time the problem of handling the long lengths of hose required for these comparatively quick-moving machines is being studied.

The conveying equipment under development includes an interlocking design in which there are coupled together a number of short portable cascading conveyor units. Each conveyor unit is driven by a hydraulic motor, and when a number are coupled together they can be driven by a central power pack. Their light construction and small size permit the conveyors to be easily manœuvred through the props in a pit or used in stable hole work. Trials are being carried out on a new form of intermediate conveyor drive, in which the belt is driven by a group of troughing pulleys in the idler line. These pulleys are driven through a line shaft and gearboxes along one side of the conveyor, and they are of grooved rubber construction to impart a non-slipping drive. This form of conveyor drive can be either used as the prime mover or it can be fitted into an existing installation to serve as a boosting device. The reduced tension required with this drive enables thinner belts to be used and simplifies belt routing. The test length of belt conveyor with this form of drive which has been set up on an open site at the establishment is illustrated on page 894.

A form of chain belt conveyor now under development has a positive drive in which most of the tensile load is carried by the chains so that a reduced thickness of belt can be used. It has an improved plough which guides the coal off the belt, and provision is made for moving over the drive and return units by means of hydraulic jacks. Investigations are also in hand in connection with belt cleaners, idlers and the use of the Milik belt turning angle station in conjunction with the new continuous mining systems.

An underground tunnelling machine which is being developed for driving 18ft diameter main locomotive roadways in new colliery projects has been built in model form. It will be capable of driving through the hardest coal-measure rocks, and a special test rig has already been used for trials with cutting tools. The head of this machine will be fitted with contra-rotating discs driven by four 160 h.p. units, and it will carry a series of roller cutting and bursting tools arranged in groups. This cutting head will be fed forwards by rams of about 5ft stroke from a thrust head at the rear. The thrust head will be supported in the tunnel by jacks round its periphery and the space between the two heads will provide sufficient room for the installation of tunnel lining, if necessary. Pads operated by jacks at the rear of the cutting head can be extended as necessary to control the direction of the tunnel drive.

These brief notes on some of the projects being developed at the Central Engineering Establishment can give only an impression of the magnitude and variety of the work upon which it is, or will be, engaged. The essentially practical nature of the work in progress and of that which is planned gives promise of many new and improved means for promoting greater efficiency and economy in production, with valuable savings in manpower, in all phases of coalmining. Although the establishment has been effective for only a relatively short time, it has already shown that it is going to take an important place in the organisation of the coalmining industry of this country.



The Short "S.C.1" vertical-take-off research aircraft is powered by five jet engines

Powered Lift

THE accompanying illustration shows the Short S.C.1, previously known as the P.D.11, a research aircraft intended to achieve vertical take-off or landing by means of jet lift. The thrust is derived from five Rolls-Royce R.B.108 engines.

The aircraft has successfully completed taxiing trials, and will carry out a programme of flying as a normal jet-propelled aircraft. The initial "flights" as a hovering machine will take place tethered in a test gantry at the Belfast works of Short Bros. and Harland, Ltd.

Fixed-wing v.t.o.l. aircraft which have flown up to the present have had only one direction of motion and have taken-off with their longitudinal axes vertical : thus, an additional undercarriage has been necessary for any horizontal take-offs. Such aircraft have the problem of adjusting the pilot to a change of attitude, as by mounting his seat in gimbals, and have approached transition through long and cautious test programmes. In the case of the previous British project, the Fairey F.D.1, transition was not achieved, principally because of the formidable control and stability problems threatening. The Short aircraft takes off along its z axis and avoids certain of these problems, but requires additional power plant to provide jet lift. Proposals for such aircraft have been made public, and the Rolls-Royce "Soar," giving 1860 lb thrust with a weight of 275 lb, was considered as a prospective engine for such use. Light weight is clearly more important than fuel economy for an engine used only at take-off and landing, and the "Soar" had a specific fuel consumption of 1·26 lb per lb thrust per hour. Since only one type of engine is used in the S.C.1, it may be assumed that it is a derivative of the "Soar" with a longer life and lower fuel consumption, achieved probably at a sacrifice in thrust per weight ratio. The lifting engines must be distributed about, and preferably close to, the centre of gravity, and so the prominent air intake near the tail will probably feed engines intended solely for thrust : for the engines used at extremely low speeds forward-facing intakes offer no advantage. The dark area behind the cabin may be a blanked off intake. Considerations of thrust-weight ratio suggest that at least three of the engines would be used to give the ability to hover.

Control of a fixed wing aircraft in the hovering state may be by control of the lifting jets, as proposed for the F.D.1, or by separate jets as on the R.R. "Flying Bedstead." The projections such as that under the nose probe in the picture are clearly for separate control jets. Stability being absent from powered lift aircraft, an auto-stabiliser has been developed by Short Bros. for this machine. The undercarriage has very little travel left in the static case, and must resemble that of the "Seamew" in possessing a long damping movement for the initial contact.

The large area of glazing shows that the research aircraft is intended only for low speeds, but the small swept tail resembles that of a high-speed aircraft : it may be that this machine, like the S.B.5, is a flying model of a more ambitious project. The tail is small compared to those of many delta aircraft, but the fuselage is presumably elongated to accommodate the thrust engines.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

STEEL RAILWAY SLEEPERS FOR FLAT BOTTOM RAILS

No. 500 : 1956. Price 3s. 6d. This standard has been revised to provide for the change in practice in ordering railway sleepers, and the requirements in respect of British Standard sections for sleeper bars are no longer included in it. To provide for purchasers who prefer to check the dimensional tolerances on a sleeper rather than check the gauge of a short length of test track, full dimensional tolerances are included in an appendix to the specification.

The standard deals with the quality of steel, provision of test samples, templates and gauges, method of manufacture, cleaning and dipping and inspection during manufacture.

Manufacture of a Whale's Head

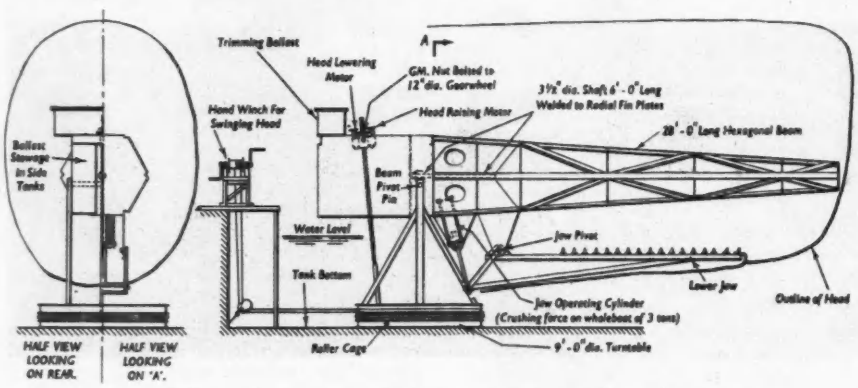
Engineering firms are frequently faced with unusual manufacturing problems, but when David Budworth, Ltd., undertook the design and production of a working replica of a whale's head, for a film company, in eight weeks, the firm certainly embarked upon an exceptional job. This article, dealing with the construction and operating mechanism of the head, shows how, by the use of the most readily available materials and equipment, a relatively simple yet quite effective working replica was produced.

ALTHOUGH it is fairly common knowledge that engineers play a large part behind the scenes in providing many of the spectacular effects used in motion picture making, it is not often that information becomes available of a particularly interesting piece of work of this nature. For this reason we had no hesitation in welcoming the recent offer of David Budworth, Ltd., Harwich, to provide some of the "background" on the head of the sperm whale used in making the film "Moby Dick." This firm had no previous experience of film making or its requirements and the notes we received from Mr. D. Budworth describing the initial stages in the "conception" of the whale are, as will be seen from the following, well worth reproducing.

"One morning when we had a telephone call from the chief engineer of a film company to ask if we could make him a whale in eight weeks, we could find no reference at all in buyer's directories to any firm specialising in the manufacture of whales, nor could we think of anyone in the country with experience in the manufacture of such a product. If the head were not completed in the time specified, the famous actor who had the leading part would no longer be available, as he had to return to the United States, and the film would just not be made. It takes some time to begin to think in terms of whales, and when we visited the officials of the film company the next day, we had very little idea of what was likely to be involved. Drawings of the head of a sperm whale were produced, made to scale from one in the Natural History Museum; also, a small model of a head with a whaleboat and crew stuck in the mouth as a particularly succulent morsel. The whale's head was to make every possible movement and was to finish by picking up a 25ft whaleboat and crew in its mouth and crush the whaleboat after spitting out the crew!"

A photograph of the model upon which the head of the whale was based is reproduced on this page, together with a drawing of the head and mechanism eventually developed and built by the firm to fulfil the requirements. When completed the head was 30ft long and weighed 20 tons before it was installed in a tank at the film studios. The head was built round a hexagonal main beam member of fabricated steel plates and angles 28ft long. Towards its rear, or body end, the beam was supported on heavy channel columns through 3½in diameter pivot pins. These columns were carried by a 9ft diameter turntable, and the weight of the front end of the main beam was counterbalanced by pig iron in boxes arranged pannier fashion at the overhung rear end. A smaller box on top at the rear end was used for the storage of ballast required for trimming purposes when the head was erected in the tank on site.

Over the main beam there was fitted a large framework of wood and wire mesh accurately dimensioned and shaped for a whale's head. Over this framework the film company moulded a coat of rubber composition to a thickness of 2in and treated its surface to impart the appearance of a whale's skin, together with the necessary warts and barnacles. This outer skin and its framework alone weighed some 4 tons. The underpart of the head was recessed to form the roof of the mouth into which the lower jaw fitted.

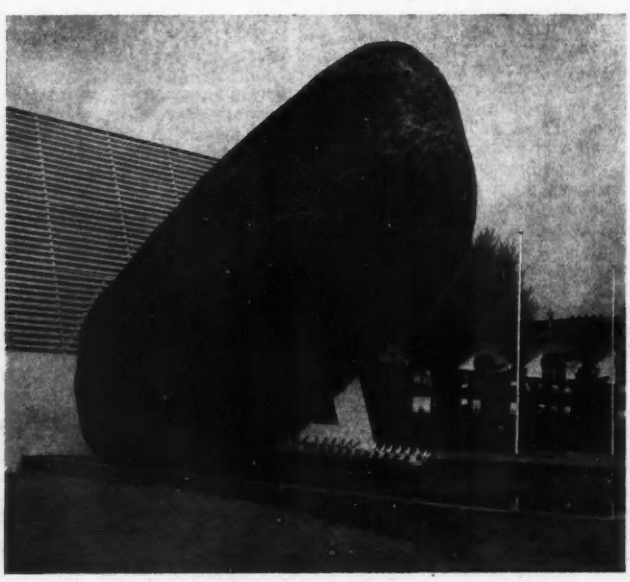

Trimming Ballast
Head Lowering Motor
GM. Nut Bolted to 12"dia. Gearwheel
3½" dia. Shaft 6'-0" Long Welded to Radial Fin Plates
Head Winch For Swinging Head
Head Raising Motor
20'-0" Long Hexagonal Beam
Ballast Stowage in Side Tanks
Beam Pivot Pin
Water Level
Jaw Pivot
Tank Bottom
Lower Jaw
Outline of Head
Jaw Operating Cylinder (Crushing force on whaleboat of 3 tons)
HALF VIEW LOOKING ON REAR.
HALF VIEW LOOKING ON 'A'.
Roller Cage
9'-0" dia. Turntable

Structure and mechanism of the whale head

When it came to designing the lower jaw some difficulty was experienced in that it was not easy to estimate the exact power which would be needed to crush a whaleboat in the required spectacular manner. The film company insisted that the boat should be completely crushed and that the jaw should bite it with a good snap. (Mr. Budworth says that "at the last moment the film director lost his nerve to some extent and asked if we were quite certain it was safe. We said that in accordance with the specification it would make a meal of anyone in the mouth at the wrong moment. Finally, in considerable trepidation, we had to offer to put one of our own technical staff in the mouth.")

Model supplied to the manufacturer depicting the requirements for the full-sized replica of the whale's head

The lower jaw was built round an angle iron framework and pivoted from brackets depending from the main head beam at the rear of the roof of the mouth. It was fitted with rows of 2in long aluminium teeth and had a moulded rubber skin similar to that of the remainder of the head. To give the required "snapping" effect it was decided to operate the jaw by means of a double-acting pneumatic cylinder. This cylinder, of 8in bore and 4ft stroke, was mounted on trunnions on a bracket in the roof of the mouth and its piston-rod pivoted to an extension of the jaw beam. When it came to designing the mechanism for pivoting the head up and down through 90 deg., so that the mouth rose clear above the water level, a positive means of operation had to be introduced in view of the danger to life if control was lost at any stage. Although it was considered preferable to use hydraulic operation it was found impossible to get a cylinder of the required size in the time available. For this reason, and to avoid the use of both hydraulic and pneumatic circuits on the same installation, a straightforward pneumatic-mechanical arrangement was adopted. In the arrangement used a long 2½in diameter square-threaded rod was pivotally anchored at its lower end to the main turntable and extended up through the inner end of the main head beam. A large gun-metal nut at the top end of this rod was located on a machined face on the beam. On this nut was bolted a 12in diameter gear wheel meshing with pinions on two air motors, arranged to rotate in opposite directions. By introducing air at 350 lb per square inch to the appropriate motor the nut was turned to raise or lower the head as required.



Whale's head exhibited at the London Zoo after it had been used in making the film

The turntable on which the complete head assembly was carried was mounted on sixteen 3in diameter rollers on the baseplate at the bottom of the tank. An endless cable, operated by a hand winch at the side of the tank, was lapped round the turntable and served to

move the assembly through 45 deg. in each direction. The makers point out that a system for turning the head on its own axis was initially developed, but the restricted time available made it impossible to get the necessary pneumatic cylinders and other equipment.

In actual service the jaw mechanism gave no particular trouble, but, with the rather unrefined control system which had to be used, it was sometimes difficult to operate the head without starting or stopping in jerks. The steel framework was stressed under static loadings to 4 tons per square inch, but it was evident that with a structure of this weight and size, considerable dynamic stresses could be set up under certain conditions unless great care was taken with its control. For instance, the director of the film thought that the whale should shake the boat like a terrier shaking a rat, and it was difficult to convince him of the complications involved in designing a 20-ton structure to move at the required speed. The whale passed its tests, and on the filming day it was operated by one of the maker's draughtsmen clad in oilskins and sou'wester, while the local firemen pumped water over the head as "Captain Ahab" harpooned the whale in the throat.

Mr. Budworth concludes his notes by saying "Now it is in the London Zoo, where it is (thank goodness) a static exhibit." The exhibit has now been dismantled, however, but we are able to reproduce a photograph kindly lent us by the Zoological Society of London.

It should be mentioned that, in addition to the above full-scale replica of the whale's head, a smaller model of the head some 7ft long was also made by the firm for use in taking certain shots for the film. In this model the head was built up on a framework on a main beam carried by a central shaft rotated by two air motors. This assembly was trunnion mounted at the top of a second beam counterbalanced and supported by pivot pins on columns on a rotating base. With this second beam the head could be swung up through 130 deg. to break through the surface of the water in the 13ft deep tank used. Further, by means of a pneumatic cylinder in the turntable, the complete head assembly could be rotated to impart an angular movement of the head through 90 deg. when it cleared the surface of the water, to give the realistic combination of movements required.

Heavy Welding Manipulator

THE welding manipulator illustrated herewith has a 94in diameter table with a nominal load capacity of 6 tons and is a recent addition to the welding equipment made by the Metropolitan-Vickers Electrical Company, Ltd., Trafford Park, Manchester. In the horizontal position the table surface is 66in above floor level and it can be tilted through an angle of 135 deg.

The machine is of fabricated steel construction, its table being designed for either constant or variable speed rotation and for power tilting. Both motions are imparted to the table through motor-driven worm and wheel gearing with automatic braking and locking mechanisms. Two high-torque squirrel-cage motors are fitted on the machine with constant speed rotation at 0·77 r.p.m. If a variable speed drive is required, one of the above motors is replaced by a variable speed motor with electronic control, giving a speed range of 0·513 to 0·0265 r.p.m. The design of the machine facilitates a quick conversion from one form of motor drive to the other.

Movements of the table are controlled from a remote push-button station mounted at the end of a 20ft length of flexible conduit so that it can be carried to any convenient working position round the machine. Loads of up to 8 tons can be mounted on the table with safety providing the centre of gravity is not more than 15in above the surface or set more than 6¾in off the centre. The installation weight of the manipulator is 3¾ tons.

Rotary Cooler for Granular or Powdered Materials

A ROTARY cooler developed by Dunford and Elliott Process Engineering, Ltd., Linford Street, London, S.W.8, incorporates the firm's arrangement of rotary louvres which are used for moving the material being cooled along drums, but in this case a flow of water provides the cooling medium. A two-stage cooler of the new design is shown in the illustration below, with its outer shell cut away and the drums partly sectioned to show the relationship between the cooling louvres, the bed of material being cooled and the circulating water.

The drums, revolving slowly on a horizontal axis, are partially immersed in a bath from which they collect water in the hollow tapering louvres formed along their sides. The collected water flushes along the outside of the louvres in the opposite direction to the movement of the material in the drums, to give a high degree of heat transfer. The water bath is split into stages, a level control determining the rate of cooling water flow through the unit. Evaporation which takes place on the outside of the louvred drums assists the cooling operation, the resulting vapour being discharged through a vent at the top.

The hot material is fed in through an opening on the centre line of the cooler and forms a moving bed based on its angle of repose. The hollow louvres in each stage are deeper at the feed than discharge end, so that they assist positive movement of the material through the unit and provide the required head for flushing the water. As the drums revolve, the inclined louvres enter the bed of material and produce a gentle movement from the bottom to the top of the bed. The uppermost particles gently roll over, maintaining the angle of repose with a spiral movement of the material from feed to discharge end, assisted by transfer vanes between the first and second stages. No avalanching or cascading occurs in the drums, so that friable materials are handled with a minimum amount of breakage. The depth or quantity of material in the cooler determines its retention time, and this may be varied by adjusting the discharge vanes.

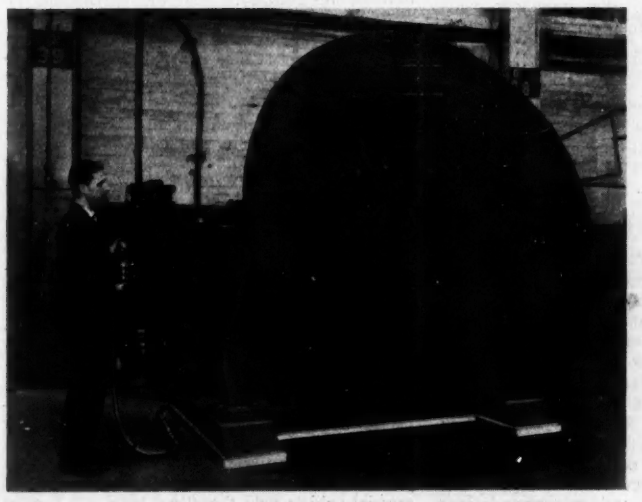
These rotary coolers are manufactured with either one, two or three stages and in a range of diameters and lengths for capacities up to 15 tons per hour. They are suitable for most crystalline, granular or powdered materials provided they are not of a sticky nature. When handling materials containing moisture which will evaporate during cooling, low-velocity air can be passed through a cooler. Normally, the parts in contact with the material being handled are of mild steel, stainless steel or aluminium, the water bath and its enclosures being of galvanised mild steel.

Technical Reports

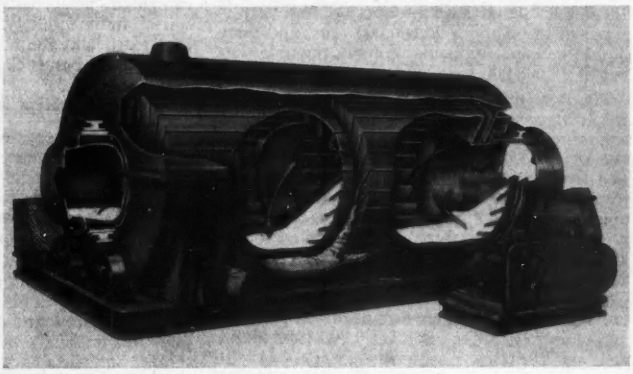
Some Experiments on an Effusion Cooled Turbine Nozzle Blade: Current Paper No. 267. By S. J. Andrews, H. Ogden and Jane Marshall. H.M. Stationery Office. Price 5s.—An experimental and theoretical investigation was carried out on effusion cooling of a turbine nozzle blade in a cascade tunnel. The permeable surface of the test blade is made of woven stainless steel wire cloth brazed to the spine in such a way that the effusion flow can be individually controlled over a number of regions on both convex and concave surfaces of the blade form. In this way the chordwise effusion, flow distribution required to produce uniform surface temperature at midspan, and the temperature distribution at mid-span produced by uniform effusion are determined and compared with the corresponding theoretical predictions.

In the laminar flow region of the blade boundary layer the effusion flow to achieve a required temperature is much higher, and in the turbulent flow region lower, than predicted. The two requirements combine to give an overall cooling effectiveness for the blade surface which is very little different from an internally cooled impermeable rotor blade also tested in a cascade. The large effusion flow required in the laminar region may be due to the practical limitation of the number of individually controllable effusion regions, since the static pressure gradient over the leading edge part of the blade surface is very large and the variation in effusion cooling air supply pressures required must also, therefore, be very large. The solution to this problem lies in the use of permeable materials of either variable permeability or variable thickness over a relatively wide range of permeability or thickness.

Efficiency of Adhesives for Wood. Forest Products Research Bulletin No. 38. H.M. Stationery Office. Price 2s. 6d.—During the past sixteen years the Forest Products Research Laboratory has been investigating the durability of all types of glues in wooden joints. The work includes tests in which the joints are exposed to various natural environments for periods of up to ten years. This bulletin describes four investigations on adhesives for plywood manufacture and five on glues for assembly work. Each of the nine experiments is described in detail, the method of analysing the results is explained, and the results themselves are given. A table is included which shows at a glance the behaviour of different types of glues in various natural environments.



6-ton capacity manipulator with a 94in diameter table rotated and tilted by electric motors controlled from a remote push-button station



Two-stage rotary louvre cooler with shell and drums sectioned to show the contra-flow of cooling water and material

Industrial and Labour Notes

Iron and Steel Prices

At the end of last week the Iron and Steel Board announced details of increased prices for iron and steel products, which came into effect on Monday, December 17. On average, the increases represent about 6 per cent on prices ruling prior to that date. In the case of most products, however, the increase is lower than 6 per cent, though in a few cases, such as plates, heavy sections and some foundry pig iron, the Iron and Steel Board's price review has established the need for a greater increase in the interests of economic development.

The Board points out that the iron and steel industry has carried increased costs in the charges for inland transport, coal and wages since the spring, and later in the year—though before the closing of the Suez Canal—there was a further increase in the landed cost of imported materials. Although it has been possible for the industry to offset these increases to some degree by improved efficiency, the net burden, the Board says, remains substantial. The Board has now carried out a comprehensive review of the price structure in relation to operating and capital costs, the greater capital now employed in the industry, and the programme of current and future development. It says that the price changes reflect the substantial net increase in the cost of production referred to and some adjustment of margins. The Board is satisfied that this is necessary to support the heavy capital investment for the continuing expansion of the industry which is needed for the provision of an adequate, efficient and economic supply of steel. This, the Board comments, requires that prices should reflect the cost of production and reasonable capital charges at modern plant. But no allowance has been made in prices for such increase in costs as has arisen, or is likely to arise, from the repercussions of the Middle East situation, or the continued hardening in the cost of imported materials and ocean freights. The Board warns that these may be substantial, though neither the duration nor the net effect can yet be forecast.

During this year, the Board adds, steel prices in most steel producing countries have risen. Although an exact comparison between individual countries and products is difficult, it can broadly be said that the new prices in the United Kingdom are, on average, about 8 per cent below those ruling in Western Europe.

Steel Production and Stocks

During November steel production in Great Britain averaged 426,400 tons a week, compared with 408,600 tons a week in the corresponding month of last year. The annual rate of output in November was thus 22,172,000 tons. The Iron and Steel Board says that, so far, the 10 per cent cut in fuel oil has been offset by the substitution of coal tar fuel. Efforts are being made to overcome the difficulties in works transport and ancillary activities due to the cut in gas-diesel oil. Total steel production this year is expected to be about 20,600,000 tons, and there should be capacity available for a possible output of 22,000,000 tons next year.

Pig iron production in November averaged 262,700 tons a week, and was thus running at an annual rate of 13,660,000 tons, compared with a rate of 13,135,000 tons in November last year. The Iron and Steel Board anticipates that this year's output of pig iron will reach 13,200,000 tons. New blast-furnaces have just come into production in Lancashire and at Middlesbrough. The extra production from these plus the additions expected next year on the North East Coast, and in Lincolnshire and Scotland, should provide capacity for an expansion of pig iron output in 1957 of at least 1,000,000 tons above this year's total.

About steel stocks, the Iron and Steel Board says that preliminary results of a limited census taken on September 30 indicate that the total stocks held by consumers and merchants increased by 9·7 per cent in the first nine months of this year. This compares with an increase of 7·1 per cent in 1955 and an average post-war increase of 4·4 per cent a year. In the third quarter of this year there was a slight fall in consumers' and merchants' steel stocks, the total at September 30 being 3,999,000 tons. The Board states that the demand for steel plate still exceeds the available supply, and the building up of plate stocks in these circumstances indicates the known tendency of steel consumers to try and increase their stocks at times of active demand. On the other hand, the demand for sheets has been falling, largely, of course, on account of the drop in motor car production since the early months of the year.

Coal Production

Several questions about coal production and supplies were addressed to the Minister of Fuel and Power, Mr. Aubrey Jones, in the House of Commons on Monday. In one of them, the Minister was asked if he would give a general direction to the National Coal Board to take urgent action to secure improved production of deep-mined coal in view of the oil shortage.

In his reply, the Minister said he did not think that a general direction would be appropriate. To improve coal output two things, apart from manpower, were necessary. They were an accelerated rate of investment and improved labour relations. On the first, investment, there had been a quickening of the rate both of mechanisation and reconstruction. On the second, labour relations, the Minister recalled that the miners' leaders had recently joined the National Coal Board in declaring publicly that they would take all possible measures over the next six months to secure a better spirit in the industry. The Minister was then asked when he expected that some results would be apparent. To that he replied, that in the case of individual pits, where reconstruction had been effected, the results were already apparent. As for the output at large, he added, it was perfectly true that there was a bad deterioration in the months of September and October owing to more disputes and less Saturday working. But he trusted that the declaration by the National Union of Mineworkers would help to put that right.

The statement by the National Coal Board and the National Union of Mineworkers, to which the Minister of Fuel and Power referred, was issued towards the end of last week. It said that the Board and the union executive had agreed to defer for six months consideration of the claim for the complete removal of the disqualifications attaching to payment of the five-day week bonus. The Board and the National Union of Mineworkers, the statement continued, were concerned that output recently had not been "more buoyant," and they felt that all possible steps must be taken to safeguard the output position and to improve it. The union, the statement added, would conduct a vigorous campaign in the coalfields "to promote the right spirit" in the industry. At the end of six months, the Board and the union would meet again to consider the bonus claim.

Automation and the Consumer

A pamphlet entitled "Automation and the Consumer" has just been published by the Conservative Political Centre. It has been prepared by a panel of eight back-benchers, who are industrialists as well as Members of Parliament, but it is not a party document.

The authors suggest that automation will be a gradual development, and that its value in every way is beyond doubt. But they point out in their pamphlet that automation does not present any fundamentally new economic problems or require revolutionary new economic policies. Among the conclusions and recommendations set out in the pamphlet, there is a suggestion about "fringe benefits." It is urged that, instead of a wage increase, or in addition to a smaller wage increase, employers should agree to set aside funds for named contingencies, a step which would be advantageous for those who might have to change their jobs as a result of automation. Another suggestion made in the pamphlet is that, as automation requires good management, there should be established in this country an equivalent of the Harvard Business School to set a high standard of training.

British Transport Commission and the Universities

The British Transport Commission says it has recently reviewed its arrangements whereby contact is maintained with the British and Irish universities, with a view to the recruitment of graduates into management and technical training schemes. The Commission's need for graduates is considerable, and it is felt that students are not always sufficiently aware of the potentialities of a career in the railway service.

The Commission has therefore chosen certain of its senior officers to include in their duties the maintenance of regular contacts with particular universities and, as far as possible, with students, by visits and other means. The main purpose of these contacts, it is stated, will be to keep before the officers of the University Appointments Board and the students the opportunities provided by recruitment and training schemes for traffic apprentices; accountancy apprentices; graduate civil, mechanical and electrical engineers; engineering graduates in the signal and telecommunications engineering department, and surveyor trainees.

The Automobile Industry's Outlook

In his address at the annual meeting of Joseph Lucas (Industries), Ltd., last Monday, the chairman, Mr. A. B. Waring, said that the immediate outlook for the future of the motor car industry, apart from any short-term effects of petrol rationing, was clouded by the increase in purchase tax to 60 per cent, and the restrictions on hire purchase transactions, together with the credit squeeze. All these measures had been taken with the object of reducing home sales, and in that, Mr. Waring remarked, they had certainly succeeded. Last year, he continued, there were over 6,500,000 vehicles on the roads, on which £485 million was paid in purchase tax, petrol tax and licence fees. This year, with the increase in purchase tax, more still would be paid, and the owner of a new car must anticipate paying on the average nearly £2 a week in taxes. But in June this year, Mr. Waring said, despite all restrictions, there were 40,000 new registrations in this country. That was remarkable, he suggested, when it was realised that a private purchaser of a £400 car had to find an additional £200 for purchase tax, and if he wished to use hire purchase had to find half the total cost in cash for the initial payment.

But, Mr. Waring continued, the motor car industry had complete confidence in its future. In spite of all the difficulties that assailed the industry, due to the struggle against inflation at home and the increasing competition abroad, there were very good grounds for optimism. The automobile industry had always been vigorous and adaptable and had never lacked confidence. Effect was still being given to its major schemes for expanding and providing for more efficient production. Those additional facilities, Mr. Waring said, would become fully effective when restrictions were eased at home and overseas demands increased. The heavy commercial vehicle industry, Mr. Waring added, had established an extremely good name in export markets for the quality and performance of its vehicles, and, as a result, had maintained its position and trade overseas. In the light commercial vehicle field there had been still further extension of the use of diesel engines, bringing increased demands for fuel injection equipment.

International Congress on Rockets and Guided Missiles

THE first International Congress on Rockets and Guided Missiles was held in Paris from December 3 to 8, under the auspices of the Association pour l'Encouragement à la Recherche Aéronautique (A.E.R.A.), 1, Rue de Courty, Paris (7e). Scientists and engineers from many European and overseas countries assembled at the Ecole Nationale Supérieure de l'Aéronautique (E.N.S.A.) to hear some seventy communications and reports dealing with past achievements in rocket technology and allied sciences, and with problems which still await solution before rocket travel near the earth or in outer space can become a reality. In conjunction with the congress, an exhibition of missiles and equipment was held at the Porte de Versailles during the period December 6 to 15.

Although the congress was not concerned with the military aspect in itself, the fact that almost all major applications of rockets and teleguidance to date are military ones inevitably led to the introduction, by way of illustration, of material from this field. Equally inevitably, discussion of the most modern developments was severely restricted by military secrecy. In this connection, mention may be made of the lecture by Monsieur Bory, in which the speaker referred to the early French development of military rockets during the first world war. Experiments carried out in 1917 by Bory and Andreau, the results of which are embodied in two memoirs deposited at the Académie des Sciences, led to an order being placed for 20,000 artillery rockets of 75mm calibre. Owing to the armistice, these weapons were not put to actual use. The French work, which had yielded, among other things, general formulæ for the propulsive force and the terminal speed, was discontinued after the war and not taken up again until 1937, when studies were put in hand of air-to-air, air-to-ground and anti-aircraft rockets. German developments, especially those stemming from the invention of the Walter rocket motor, are by now well known. A systematic classification of the problems of teleguidance and a discussion of the possible solutions, with special reference to those which have found practical realisation, was given by Dipl.-Ing. F. Müller (Göttingen) in his talk "Problems and Methods of Teleguidance."

Among the questions foremost in the minds of many delegates seemed to be the problem of atomic propulsion. What practical progress there has been to date in this connection is not clear. It seems, however, to be generally agreed that the feasibility of astro-navigation, away from the earth, is bound up with the realisation of atomic rockets, because of the excessive fuel/weight ratios of chemical propellants. A further, and perhaps still more Utopian, stage is the photomic rocket, which uses the pressure of electromagnetic radiation. Such a rocket would be capable of speeds in the vicinity of that of light, with two important consequences. A vehicle travelling at such velocities would be capable of reaching the nearest fixed stars within the span of human life. The second, perhaps even more staggering consequence, was mentioned by Dr. Ing. E. Sänger (Stuttgart). The relativistic change of the rocket's time scale would lead to a very marked slowing down of all processes inside the rocket (as seen from the earth), including the vital processes of the crew, who thus might be able to reach the astronomic distances measured in terms of millions of light-years.

Whether such voyages, or even less ambitious ones, will ever be possible depends, however, upon many other problems, many of which formed the subject of lectures at the congress. The heating of the rocket when travelling at high speed in the atmosphere, and the effect of cosmic radiation on the crew, were among these, as were questions of astro-navigation and the biological problems of space flight, including the effects of the lack of gravity.

In connection with the biological aspects, mention must be made of the talk by Dr. Pokorovski, director of the Soviet Institute of Experimental Aeronautical Medicine. In the Russian experiments, twelve small dogs were sent up in pairs on a succession of flights to altitudes of up to 65 miles, some of them several times. The dogs wore specially designed protective suits and were always in separate containers, each with its own oxygen supply and air regenerator. One of the containers was expelled each time at maximum altitude, with its parachute set to open after three seconds. The other descended with the rocket to an altitude of about 25 miles when it travelled at a speed of some 2000 m.p.h. On ejection it fell freely to within 2½ miles of the ground, when its parachute also opened. No substantial physiological changes in the animals were observed. The experiments confirm earlier American work begun in December, 1946, at White Sands Proving Ground, New Mexico, when an attempt was made to discover whether fungus spores were affected in their growth or heredity by any high altitude phenomenon such as cosmic rays. In 1947, fruit flies were flown to a height of 106 miles in a pressurised container carried by a German "V2" rocket, the container being ejected and descending by parachute. These tests, and later ones carried out with monkeys, showed that no apparent damage was caused to the animals.

Among the many very striking films shown during the congress must be mentioned the first firing of a "V2" rocket from a U.S. Navy aircraft carrier in 1947, shown by Mr. A. W. Robinson (Philadelphia); a short sequence showing the Fairey "Fireflash" in action against robot target aircraft; films showing the Oerlikon anti-aircraft rocket (Dr. Gerber, Zürich), and the American "Nike" and "Honest John" rockets.

A talk by Mr. R. E. Small (Cincinnati) covered the G.E. contribution to the project "Vanguard," the artificial satellite which is to be launched during the International Geophysical Year. A brief résumé of the Russian part of the programme was also given by a speaker from the Russian delegation; it includes high-altitude atmosphere research which may be extended to a height of 1000km.

British High-Altitude Research

Information was given by Dr. Dorling concerning the British High-Altitude Research Programme, which will be carried out during the International Geophysical Year. It should be noted that this work does not form part of the I.G.Y. official programme, but would have been carried out in any event. Preparations are in the hands of the Gassiot Committee of the Royal Society in co-operation with the Royal Aircraft Establishment, Farnborough, and working in conjunction with a number of British Universities. The Gassiot Committee is concerned with research in the upper atmosphere and is co-ordinating the university work.

The rocket to be employed in this research, the "Skylark," is shortly to be tested at the Woomera rocket range.

The "Skylark" rocket has an overall length of 307in, with a cylindrical body 17·4in in diameter, and stabilised by three fins of 44in radius. It has a conical head 65in long, followed by an instrument compartment which is 30in long. It is to be launched by means of an 80ft launching tower built from Bailey bridge elements and weighing 30 tons. The tower is supported at half height by gimbals so that it can be inclined a few degrees from the vertical.

The vehicle is powered by a "Raven" rocket motor, and has a gross weight of 1160 kg, including 820 kg of propellant and a 61 kg payload. Developing a maximum thrust of about 5200 kg, with a burning time of approximately thirty seconds, the rocket at burn-out should reach a height of 21km, its speed then being 1500m per second, and travel on to reach its ceiling of 120km in a total flying time of 183 seconds. (It may be found possible to increase the ceiling to 210km.) If the Woomera trials are successful, some of the work will be transferred to the guided weapons range at Aberporth, where a second launcher is under construction.

The scientific experiments which are in preparation will include measurements of temperature and wind velocity above 30km, the latter by the grenade method, and the tracking of aluminium foil ("window").

Interferometric studies of ejected sodium vapour will give information about the interaction of sunlight (radiation) with atoms at high altitude, as well as temperatures (though temperatures will not be measured with a high degree of accuracy by this method). Equipment will be carried for carrying out ion mass spectroscopy. Various instruments will be used for measuring atmospheric pressure and density, as well as the earth's magnetic field. Instrumentation will include photographic cameras, and microphones for the registration of micro-meteorites.

Electron density is to be measured both by the continuous wave and the pulse method, in a series of experiments which are a joint undertaking of University College, Swansea, and the Royal Aircraft Establishment. The retardation of radio waves in the range 2 to 14 megacycles per second, both with continuous waves and with pulses sent from the ground to the rocket, is measured and the total electron density is calculated from the results. These experiments are stated to be of a rather complex nature and will not be ready as quickly as the other more simple ones.

Details of the Bristol "Raven" motor were given by Mr. D. C. Mandeville. The motor consists of a metal cylinder, 45cm in diameter by 480cm long, the diameter being the same as that of the rocket body. Including the nozzle, the overall length is 515cm. All-up weight is about 1000 kg. The body is fabricated either from tube sections or seam-welded sheet, which is stretch-formed and welded to the end sections. The shell consists of heat-treated, high-tensile steel, and the ends are machined forgings. A hydraulic pressure test is carried out to ensure that the motor will withstand a working pressure of 1350 lb per square inch.

The propellant is a plastic composition of ammonium perchlorate and ammonium picrate, with a polymeric hydro-carbon. It is filled at a temperature of 60 deg. Cent. and a core former is inserted in order to form a central cavity, in the shape of a seven-pointed star, and at the same time to bond the propellant to the walls. The former is subsequently withdrawn.

The nozzle is a machined steel forging with a carbon-lined throat, 10cm in diameter, of an area ratio of 12 : 1, giving slight over-expansion at sea level. Ignition is by means of a primer at the head end which is fired by a cartridge. Experiments showed the need for insulating the inside of the bottom end piece to prevent it burning out, and an asbestos phenolic insulation was successfully applied for this purpose.

European Machine Tool Committee

At its meeting in Brussels at the end of October, at which eight member countries were represented, the European Committee for Co-operation of the Machine Tool Industries dealt with questions of technological training and economic expansion.

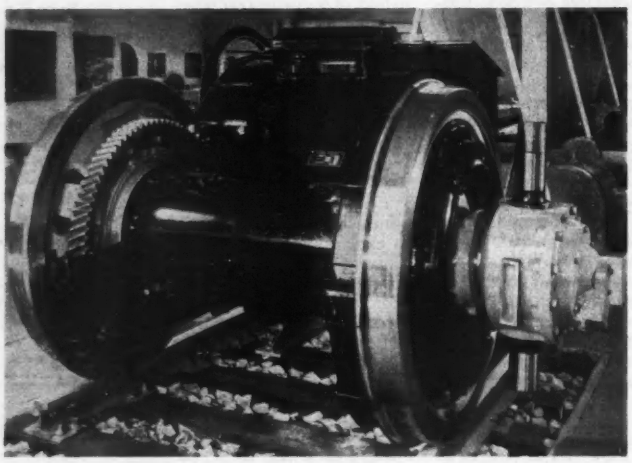
The importance of training engineers and technicians is being realised more and more, although the aspects of this problem and the recommendations vary from country to country even within the machine tool sector. It was decided to renew the international interchange of experience, on the basis of an agreed questionnaire.

A brochure in several languages is in course of preparation and will state the views of the committee on the importance of modern machine tools in every class of production.

The fifth European Machine Tool Exhibition will be held in Hanover, German Federal Republic, from September 15 to 24, 1957, and the regulations and other measures concerning the exhibitions are being finalised.

Individual Axle Drive for Electric Locomotives

Our accompanying illustration shows a heavy individual axle drive developed by Siemens-Schuckertwerke A.G., Berlin and Erlangen, German Federal Republic. Equipped with an electric motor of 1100 h.p. continuous rating, the drive can be overloaded to 1700 h.p. during periods up to twenty minutes. On starting it develops a torque of over 2000 mkg., or 2·6 times the running torque, taking a starting current of 3700A. Efficient cooling (with minimum power consumption of the fan) was therefore of great importance. Special attention was paid in this construction to long life and minimum wear of the commutator. To this end a novel design of the transmission was evolved, incorporating a system of rubber springs. From the hollow shaft driven by the motor half the torque is transmitted to each wheel by means of six circumferentially placed rubber pads which consist of a core of soft rubber vulcanised on to steel flanges. The weight of the motor is supported by these twelve rubber segments as well as by two further rubber springs on the bogie. The arrangement can be seen from our illustration. It is stated that no maintenance of the rubber pads is required. Over 200 four- and six-axle locomotives of the German Federal Railways are to be equipped with this drive, as well as thirty express locomotives of the Austrian State Railways, which have also placed an order for twenty-five smaller units for electric railcar trains.



Individual axle drive with 1100 h.p. motor (continuous rating) and rubber spring arrangement

Mr. Adolf Brunner

We greatly regret to record the death, on November 29, at the age of sixty-six years, of Mr. Adolf Brunner, chief of the Diesel Traction Department of Sulzer Brothers, Ltd., Winterthur, for many years, until his retirement at the end of 1955. On joining the Sulzer organisation in 1906, Brunner first served his apprenticeship of four years in the projects section of Sulzer Brothers. As a draughtsman he was transferred to the locomotive section in 1910, and was engaged in a junior capacity on the 1000 h.p. Diesel-Sulzer-Klose direct-drive locomotive of 1912–13. There he was brought into personal contact with Diesel himself, with Adolph Klose, and with Jacob Sulzer-Imhof. Brunner assisted also in the design and production of the 200 b.h.p. " V " engines for the Prussian and Saxon diesel-electric railcars of 1914.

At the age of twenty-eight Brunner went to the engineering school in Winterthur, to complete his theoretical knowledge, but continued at the same time his work in the office. In 1920 he was put in charge of the diesel locomotive department of Sulzer. In 1927–28 he sponsored the original Sulzer LV engines of 420 to 800 b.h.p., probably the first range of standard traction oil engines known. He was responsible also for the present Sulzer LD range, extending now from 600 to 2300 b.h.p., including the well-known twin-bank engine, of which some fifty are now at work or under construction at 2000 to 2300 b.h.p.

Brunner became a world figure in diesel traction, because of the skill with which he consistently combined the soundest judgment in oil engine and railway problems with the highest class of design and construction, and also because he similarly combined a very forceful and trenchant personality with complete integrity and generosity.

Among outstanding diesel motive power for which Brunner was wholly or partly responsible were the Argentine 1700 b.h.p. locomotive and mobile power-houses of 1933, the Roumanian 4400 b.h.p. locomotive of 1938 ; the Siamese lightweight 735 and 960 b.h.p. locomotives of 1946–50 ; and the Commonwealth Railways' 1000 b.h.p. locomotives with 10½-ton axle-load, of 1954. Power plants of his design are also to be found in the 600, 2000 and 4400 b.h.p. locomotives of the French National Railways ; in the 1000 b.h.p. locomotives belonging to C.I.E., and in the new 2300 b.h.p. diesel-electric locomotives now being constructed at Derby works for British Railways.

Adolf Brunner was a member of the Institution of Locomotive Engineers from 1947 to his death.

Use of Compressed Air Against Ice

Equipment using compressed air to keep waterways free from ice has been developed by Atlas Copco and A.B. Svenska Metallwerken. After two years' experimentation, the plant was tried out on a larger scale last winter at the port of Västerås, on Lake Mälar, Sweden. The installation comprised 1000ft of special " Neoprene " tubing fed with compressed air from an air compressor. The tubing had small holes at distances varying from 33ft from each other at the compressor end, to 16ft at the far end, and the capacity of the compressor was about 450 litres per minute. After twenty hours, the ice, which at the beginning had been about 2ft thick, had melted away in places, and after twenty-four hours holes 30ft wide had formed, making an ice-free lane of 30ft to 40ft width. Two weeks later, the lane was 60ft to 65ft wide. It was necessary to keep the compressor going all the time to prevent the ice from re-forming.

In view of the importance of all-year traffic on Lake Mälar, in particular between the industrial centre of Västerås and Södertalje, on the Baltic, studies are now being undertaken with a view to installing the system on the Västerås–Södertalje route, a distance of some 60 miles. Lake Mälar is deep and relatively free from currents, and is therefore considered to be particularly suitable for an application of the invention.

Installation of Large Radioactive Source

One of Western Europe's largest sources of atomic radiation was recently installed at the Battelle Institute, Frankfurt-on-Main. The source consists of 1500 curies of cobalt 60, and was shipped from the Battelle laboratories at Columbus, Ohio. Produced at Arco, Idaho, the cobalt 60 had been purchased from the Atomic Energy Commission. It represents a value of about 7500 dollars, compared with about 15,000,000 dollars for an equally powerful source of radium.

Among industrial researches in which the new source of gamma radiation will be used may be mentioned the radiation sterilisation of certain foods, drugs, and medical supplies which are difficult, too costly, or impossible to sterilise by conventional methods. It will also be useful in activating or " triggering " chemical reactions which are used in the manufacture of various components. In order to protect research personnel, the cobalt 60 is housed at the bottom of a large tank of water, the water forming a transparent radiation shield which permits the use of simple and inexpensive handling equipment. The source is being used in conjunction with the radio-chemistry laboratory that has been operating at the Frankfurt Battelle Institute for about a year, and will also be available for the radio-chemical work which is being carried out at the Geneva Battelle centre.

German Scrap Consumption

Reserves of scrap at German steel works amounted at the end of August to 1,164,000 tons, 64,000 tons less than in July. For the first time the monthly consumption of scrap rose to over 1,000,000 tons. Of this quantity, the steel works themselves produced 495,000 tons, an increase of 19,000 tons over the previous month. A similar increase was noted for bought-in scrap, which reached 403,000 tons. Scrap for crude iron rose by 12,000 tons to 127,000 tons, while scrap for crude steel increased by 84,000 tons to over 884,000 tons.

The proportion of scrap also increased, amounting to 84 kg (76 kg) per ton of crude iron, and 697 kg (667 kg) per ton of SM-ingots. Exports of scrap rose by 19,000 tons to 78,000 tons, while scrap imports decreased from 50,000 to 40,000 tons.

Radar for Traffic Control

The first German radar set for the control of road traffic was recently demonstrated in Berlin by Telefunken G.m.b.H. The equipment registers traffic density and the speed of individual passing vehicles. Speeds which exceed the legal limit can be recorded and at the same time the number plate of the speeding car can be automatically photographed. The set, which makes use of the Doppler effect, employs a measuring interval of 200 milliseconds, corresponding to a movement of 5m by a car travelling at 90 km.p.h. Accuracy of measurement in the range 20km to 150km is stated to be 3 per cent.

Because of its simple operation by one man the equipment is stated to be readily suitable for many problems in connection with traffic control, such as the relief of roads carrying excessive traffic, diversions, and supervision of speed limits. The total time of measurement and registration is half a second.

The Cost of Documentation

An important role is assigned in modern industry to the documentation unit. According to a recent article in the German technical press,* the head of such a department should in larger concerns have the position of director. It would be his duty to attend board meetings at which policy decisions are taken so that he is enabled to obtain in time the necessary material for instruction, information and research, and to see that the material so collected is stored and held in readiness in an appropriate manner. The minimum cost for which such a department can be run efficiently, the article estimates at DM.20,000 to DM.30,000 per year. As an upper limit, while no fast rules can be given, it would seem reasonable to set a limit of ½ to 1 per cent of the turnover. A documentation unit makes no profits itself ; its work does not so much increase the gross profits made by other departments, but rather helps to reduce their costs.

* " Chemische Industrie," No. 6/1956, page 290.

National Metal Congress and Exposition

BY OUR AMERICAN EDITOR

No. II—(*Continued from page* 867, *December* 14)

Inert Gas Shielded Welding

AN important new process in the field of "Heliarc" welding was demonstrated by the Linde Air Products Company, of New York. The troublesome use of frequency, previously necessary for most arc starting, has now been eliminated with mechanised "Heliarc" spot welding. The well-known process has been greatly improved, especially in multiple spot welding operations, by the addition of pilot arc starting. With the pilot arc device, the operator is sure of arc starting every time, because the perpetual pilot arc is always ready within the torch cup. Heat for the neat, localised fusion weld is produced by an electric arc between a tungsten electrode and the workpiece. When the welding arc is needed, it is automatically started by the pilot arc. The welding action is controlled by the current input to the arc, and the time the arc is sustained on the workpiece. Inert argon gas shields the weld area from the atmosphere, protecting the weld puddle and the electrode from contamination. Argon is used because it requires less gas flow and blankets the weld area better than any other shielding gas.

Mechanised "Heliarc" multiple spot welding is a precision process. The entire operation is controlled and exact, and is subject to a high degree of statistical prediction. It is extremely valuable in industries which require high-speed production. For example, welding the torus shell to the vane assembly on an automatic transmission torus assembly is an operation requiring eighty-two spot welds on a single transmission. With the probability of weld failure below 0·5 per cent, the completed transmissions are produced at a rate of one every forty-five seconds, and as many as eighteen torches are fired simultaneously. The spot welding process produces outstanding results on large assemblies or irregular shapes which are impractical or impossible for other types of spot welding. Welds are made from one side only—they leave no "dimples" on the outside which require grinding and polishing. The mechanised operation of the apparatus is simple and no exceptional skill is required. There is no limit to the number of torches that can be hooked together to obtain a single automatic operation.

It may be recalled that at last year's Metal Show the Linde Company introduced its "Heliarc" gas-shielded arc cutting process (Fig. 5). It is stated that production experience at the Edge Moor works of the Graver Tank and Manufacturing Company has confirmed speeds on manual and mechanised arc cutting ranging from 37in to 62in per minute through ¾in aluminium plate. The arc cutting technique here plays an important part in the fabrication of 10,000 gallons low-pressure aluminium vessels. The tanks are 30ft long by 7ft in diameter, and are constructed of "52S" aluminium alloy plate, ¾in thick. The dome holes atop the tanks are manually cut in four and a half minutes. The holes are 54in in diameter, involving a running cut of 170in, the average cutting speed being 37in per minute. The dome holes were previously chipped by power tools. At least five hours per hole were required, and the production time of the operation now amounts to less than 5 per cent of the former figure.

The major problem in flame or arc cutting such non-ferrous alloys as aluminium has been thermal conductivity. In aluminium this ranges from 0·26 to 0·54 C.S.G. units, compared with 0·11 at room temperature for a typical carbon steel. Heat is rapidly dissipated by aluminium, unduly lengthening the time required to reach the melting temperature. The answer lies in the rapid heating of the aluminium, so that even heat-treatable alloys are affected only locally. Arc cutting deliberately employs a harsh arc. The arc is restricted by a small diameter orifice in the cutting nozzle. Carefully pointed electrodes are used, and proper centring of the electrode is very important to obtain high-quality cuts. The cutting temperature is so high that the nozzle head must be continuously cooled. Since this arc is highly constricted, the operating voltage of the arc is abnormally high. A power supply is required which gives high current at that operating voltage. The only power supplies commercially available to give these power requirements are motor generators or two rectifiers connected in series. The result is a concentrated arc stream $^{5}/_{32}$in or less in diameter. This stream melts an extremely localised area almost instantaneously. In aluminium plate up to 1in thick, the arc plunges through the metal and flings molten aluminium away from the kerf. The finely divided aluminium particles rapidly solidify and settle as dross. Despite the high speed, the resulting cut is clean and smooth. It closely resembles the better cuts produced in steel by an experienced operator with an oxy-acetylene torch. The following table shows the speed of the arc cutting operations now being performed at Graver Tank :—

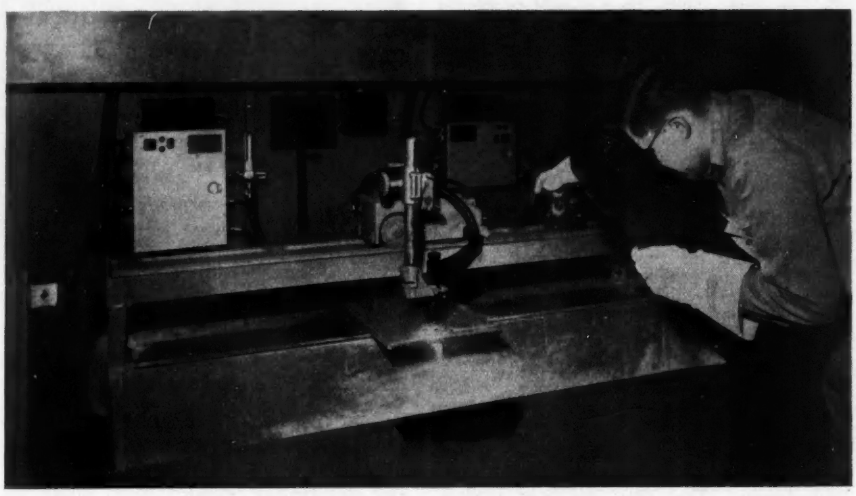


Fig. 5—Linde "Heliarc" gas-shielded arc cutting machine cutting aluminium plate

Operation	Length, inches	Sawing or chipping time, minutes	Arc cutting time, minutes	Rate, inches per minute
Cutting :				
54in diameter... ...	170	300	4·54	37
18in diameter... ...	56·5	—	1·0	56
11in diameter... ...	35	—	0·75	47
7½in diameter... ...	25	—	0·60	42
Shaping :				
Stiffeners...	137	27	2·35	58
Bevelling :				
Stiffener ends (both)	26	—	0·45	58
Inner arc...	54	—	0·81	62

A new process demonstrated by the Arc Welding Department of the Westinghouse Electric Corporation, of Buffalo, New York, involves the application of the firm's inert-gas-shielded metal-arc welding equipment to spot welding. The apparatus for performing arc spot welds is an adaptation of the standard semi-automatic or manual inert-gas-shielded metal-arc gun and wire drive unit. Two special nozzles were developed for the gun. One slips over the nozzle and is intended for short-run work or work where it is necessary to change nozzles rapidly and frequently. The second is a set of nozzles which replaces the standard nozzles on the gun. They are fastened to the gun by an adapter and a threaded ring. These nozzles are water cooled and are more suited to production work where many identical welds are to be made and where the duty cycle is high. Nozzles for plug welds, inside corners and outside corners or fillet welds are available in both designs. The following changes were made in the standard wire drive control :—(1) Automatic inching of wire ; (2) preweld gas purging ; (3) welding timing ; (4) wire "burn-back" control, and (5) addition of a selector switch for manual, automatic or spot welding.

When the trigger of the welding gun is pulled, welding wire is inched slowly toward the work. Control of the inching speed is achieved by a potentiometer in the grid circuit of the thyratron tube which controls the wire feed speed. This control is, in effect, the preweld gas purge timer. If the inching speed is low, a long purge time is achieved, and, conversely, the purge time is short if the inching speed is high. When the welding wire strikes the work, welding current flows and a current relay in the control transfers the wire speed control from the "inching speed control" to the "welding speed control," which is in the gun. Weld timing is also initiated by the current relay. Weld timing is accomplished with a pneumatic timing relay which is calibrated from 8 to 360 cycles. For most applications, this timing device has proved satisfactory ; however, several applications have been encountered where more accurate timing was required. In these cases an electronic timer is employed.

To prevent the welding wire from sticking in the molten pool, the wire must be "burned back" at the end of each weld. This is done by a fixed-time-delay relay in conjunction with adjustable dynamic braking in the feed motor armature circuit. On small diameter wires which are driven at speeds up to 600in per minute, the braking resistor is set at a low value for rapid stopping. As the wire size is increased the value of braking resistance is increased and adjusted so that the desired "burn-back" is obtained on the wire after each spot. The control sequence circuit is designed to be non-beat and non-repeat. Once the gun trigger is pulled, a complete weld will be made even though the trigger is released in the middle of a weld. The trigger must be released after each weld and pulled again to initiate the next weld. The gun and wire drive control equipment are designed to operate in conjunction with a constant-potential rectifier welding set. The use of a constant-potential machine is desirable for several reasons : the lower arc voltages as compared to those obtained from other power sources makes the welding arc less critical and gives little or no "burn-back," such as is experienced with higher arc voltages from other power sources. With the particular equipment discussed the readily accessible wire-feed adjustment in the handle of the gun can only be utilised on a constant-potential source as a current control. The welding set is equipped with a primary

contactor and an auxiliary relay for operating it. A transformer in the welder supplies 110V, a.c., for operating the control. In addition to the gun, wire drive control and welding set, a source of cooling water, a water drain, a gas cylinder, a gas regulation and flow meter, and gas and water hoses are required. Standard stationary equipment may be used where the equipment is to be installed in a booth for high production welding. In many shops, the versatility of this equipment can best be exploited by mounting the equipment on a rubber tyre running gear so that it can be moved from one place to another in the shop.

Resistance Welding

Probably the most significant development introduced at the 1956 Metal Show in the field of resistance welding is the "Predetermined Electronic Counter Weld Control," applied to three-phase machines by Sciaky Brothers, Incorporated, of Chicago, Illinois. The control has been designed to ensure absolute weld consistency and reproducibility. The heart of this new control, which counts cycles of line frequency, is the "dekatron" valve. This is a glow transfer gas valve having ten cathodes with two guide elements between each pair of cathodes. The cathode, on which a dial setting is made, will glow when power is applied to the valve. When the counting operation is started, pulses are fed to the guide elements and thus the flow is transferred from one cathode to the next until the count has been completed. This count may be any amount from one to ten, and by adding a decade "dekatron," the count can be increased to 100. Adding a third dekatron will increase the count to 1000. Pulse counting circuits and commutating stepping circuits are used to obtain a desired sequence of operations. A three-phase spot welder is used having four functions—"squeeze," "weld," "hold" and "off." The weld period is measured in terms of pulses while the other three functions are measured in terms of cycles of line frequency.

The system in general consists of four major divisions: (1) an overall function stepping timing circuit; (2) a cool, heat and current decay timing circuit; (3) a rectifier pulse forming and firing circuit, and (4) a relay sequence including time delay, safety, head retraction and foot switch circuits. In the quiescent state, the cool, heat and current decay "dekatron" system is at rest in the cool function, the "dekatron" valve being preset for the cool time count. When the pulse forming gate is opened, the "dekatron" receives pulses which cause the glow to transfer from the preset position as each pulse at line frequency is delivered. At the end of the preset cool time count, an output pulse is delivered from the "dekatron" to the cool, heat and current-decay function stepping circuit which switches to the heat position. When this switch is made, a reset pulse is delivered to the "dekatron" which sets the glow at the proper cathode for the heat time count. Pulses at a line frequency rate continue to be delivered to the "dekatron," and after the preset heat time, an output pulse is delivered from the "dekatron" to the function stepping circuit which switches from the heat stage to the current decay stage at which time a reset pulse is delivered to the "dekatron" which presets the glow for the current decay time. At the end of the proper number of cycles a pulse is again delivered to the function stepping circuit which switches the circuit from the current decay stage to the cool stage. At this time a pulse is delivered to the reversing circuit which switches and shifts the pulses coming from the pulse forming network by 180 deg. These pulses step the "dekatron" which has been reset for the preset cool time count, and the circuit continues to operate as above. After each current decay time the pulses coming from the pulse forming network are switched through 180 deg.

The function stepping system consists of a pulse forming network, "dekatron" reset circuits and function stepping circuits, as in the cool, heat and current decay system with the addition of a number of gating circuits. One gating circuit has the function of turning on and off the pulse forming network feeding the function stepping circuit and the second group of gating circuits control the pulse forming network of the cool, heat and current decay circuit. The pulse forming circuit No. 1 can accept pulses at 60 c/s from the line, or pulses at the repetition rate of the cool, heat and current decay sequence developed at the beginning of each cool time. Gate No. 1 allows pulses to be delivered at the line frequency when the function stepping circuit is in either the squeeze, hold or off stage. Gate No. 2 allows pulses at the line frequency rate to be delivered to pulse forming circuit No. 2 when the function stepping circuit is in the weld stage. When the system is at rest, the function stepping sequence is in the squeeze stage and the "dekatron" has been preset for the squeeze time count. The squeeze time gate is held closed by means of a manual switch. When this switch is thrown, the squeeze time gate is opened and pulses at the line frequency are delivered to the "dekatron" which steps along at a line frequency rate.

Pulses are delivered to the "dekatron" until the preset squeeze period is over and then an output pulse is delivered to the function stepping circuit which switches to the weld stage. Gate No. 1 is closed, thus stopping the delivery of pulses at the line frequency from the pulse forming circuit No. 1 to "dekatron" No. 1, and gate No. 2 is opened, allowing pulses at line frequency to be delivered to the cool, heat and current decay "dekatron" valve circuit. At the end of each current decay period when the switch is made from the current decay to the cool function, a pulse is delivered to the pulse forming circuit No. 1 which, in turn, delivers a pulse to the "dekatron." At the end of the preset number of pulses the "dekatron" sends a pulse to the function stepping circuit which moves to the hold stage. Gate No. 2 is then turned off and gate No. 1 is turned on. At the end of the preset number of cycles of hold time, the "dekatron" delivers a pulse to the function stepping circuit which switches to the off time. If the sequence is in "non-repeat," the system will remain at rest until the foot pedal is released, at which time the sequence will be preset to the squeeze time ready for the next weld. The rectifier pulse-forming circuit receives signals from the cool, heat and current decay and reversing circuits in order to fire the two rectifiers of the control in sequence. Gating signals are delivered from the function stepping circuit, which allow the peaking signals at the proper phase angle to be delivered to the rectifier at each of the periods during which time the rectifier is to be fired. The weld control can be applied to spot, seam and roll spot resistance welding machines.

Quality Control and Inspection

An interesting display of gamma radiography equipment was presented by the Nuclear Systems Division of the Budd Company, of Philadelphia, Pennsylvania. This firm has only recently entered this field, but already is offering a very comprehensive range of sources and manipulating gear. While the company offers various isotopes, it stresses the usefulness of iridium 192, particularly in work involving the lighter sections. The radiation from iridium 192 is appreciably "softer" than that from cobalt 60. As a result, it is useful for the radiography of thinner sections, its useful range in steel being from approximately ¼in to 3in. While the radiation output per curie is less than that from cobalt 60 (5950 mr/hr at 12in for iridium 192), it is available in very much higher specific activities. The most common source size for industrial radiography is ¼in in diameter by ¼in long, which allows the use of sources containing up to 30 curies. Two such pieces can often be contained in the same source capsule, resulting in a total of approximately 60 curies. Such strong sources reduce exposure times to the point where they become competitive with those of medium voltage X-ray machines, and for certain applications the quality of the radiographs obtained compares very favourably with the quality of the radiographs obtained with X-ray machines.

The relatively short half-life of iridium 192 (seventy-five days) is sometimes considered a disadvantage. However, the method used by nuclear systems for replacing sources has completely eliminated any problems arising from the short half-life. The replacement sources are shipped to the customer at specified intervals in new or reconditioned heads. The customer merely replaces the old head with the new and returns the old head in the same shipping container, thus avoiding any problems of disposal of the old sources. The machine is shut down during the change-over for less than five minutes.

The company exhibited its new "Iriditron" (Fig. 6), a lightweight radiography machine especially designed for the remote exposure of sources of iridium 192 in industrial radiography. It is one of the more versatile radiography machines on the American market, being capable of producing a beam of gamma radiation which can be directed at the specimen. It can also be used to expose the iridium source by remote control at distances up to 50ft from the operator,

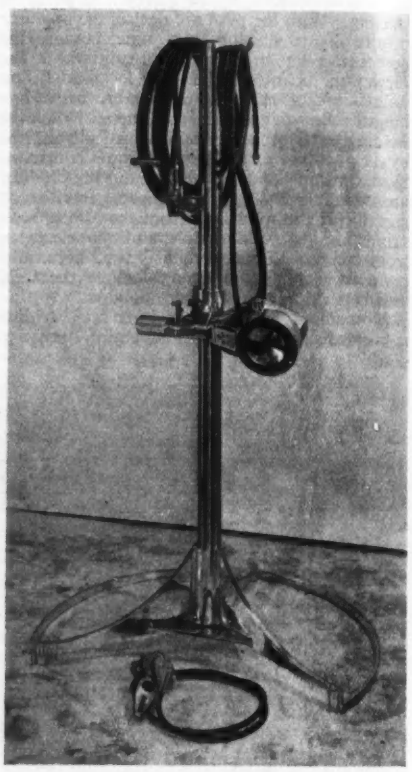


Fig. 6—Budd "Iriditron" lightweight gamma radiography machine with iridium 192 source

who may remain behind a shield during the exposure. The "Iriditron" also serves to store the iridium source when not in use, and the shielded head serves as a shipping container. This instrument is capable of many of the radiography functions of a medium voltage X-ray machine and in addition allows a versatility in internal and panoramic exposures not found in X-ray equipment.

The machine consists of (1) the shield or "head" within which the source is stored when not in use, (2) a mount which allows the head to be aimed in any direction when the machine is used as a beam producer, and (3) control cables and source tubes which are used to expose the source beyond the collimating cone. The unit is available in either of two models: model 10, which has a capacity of 60 curies of iridium 192, the head of which weighs approximately 95 lb, and the model 30, which has a capacity of 30 curies and the head of which weighs approximately 55 lb.

The shielding of the head of the "Iriditron" has been carefully designed to provide maximum protection for a given weight and curie capacity. Each machine also has a source position indicator. This device, which is entirely mechanical in construction, indicates at all times the exact position of the source relative to the shielded position. As a result the possibility of accidental

exposure of the source is minimised. Each machine is equipped with a lock, which is so designed that the machine cannot be locked unless the source is properly positioned with the shield.

The two basic functions of the machine, beam production or remote handling of an essentially bare source, allow a variety of radiography techniques in the shop or the field. For example, in the field where personnel shielding may not be available, the use of the "Iriditron" as a beam producer allows the operator to stand or work directly behind the machine while an exposure is in process. On the other hand, the use of a source tube which allows the source to be moved from the shield to a predetermined position allows a variety of internal and panoramic exposure techniques. For example, the entire girth weld on a pressure vessel may be radiographed with a single exposure, or a relatively large number of individual pieces may be radiographed simultaneously by arranging the pieces with their films in a circle around the end of the source tube. The flexible source tube may, if desired, be replaced with a rigid tube of any length up to 23ft. While these tubes are rigid they may be bent around moderate radii for fixed internal or panoramic set-ups. These rigid tubes will retain their position as the source passes

Fig. 7—Transportable 1MeV Van de Graaff super-voltage X-ray machine

through them, and they are very useful where a series of shots of the same approximate geometry are to be made. It is of interest to note that, in addition to various gamma radiography sources and machines, the firm offers radiation level survey meters, direct-reading pocket dosimeter chargers, and shielding equipment. It also now runs a film badge service for the monitoring of the cumulative radiation doses received by operators.

Various new applications of "super-voltage" X-ray techniques for non-destructive inspection in the metals industry were shown at the stand of the High Voltage Engineering Corporation, of Cambridge, Massachusetts. Of particular interest were the radiographs illustrating the use of the company's Van de Graaff "super-voltage" X-ray generators in circumferential radiography. In "super-voltage" radiography the X-rays generate in all directions. With the Van de Graaff machine, X-rays in a particular sector can be selected by the use of special absorbing diaphragms, providing either a conical beam in the forward direction or a wider, sideward beam for panoramic radiography. With this latter improvement groups of castings can be placed in a circle about the X-ray tube axis to obtain single set-up, single exposure, simultaneous radiography. Another example of this technique which was demonstrated at the Show is the use of the panoramic beam for the study of complete girth seams of welded pressure vessels, also in one exposure and a single set-up.

The wide-range flexibility of the Van de Graaff machine in the inspection of both light and heavy materials was also shown. Radiographs produced by the company's versatile 1 MeV unit in single-exposure studies of a precision jet blade casting with thicknesses varying from $\frac{1}{8}$in to well over 1in were displayed. The Van de Graaff unit is an X-ray machine designed to cover the range from fractional thicknesses to those beyond 5in in steel. The accompanying illustration (Fig. 7) shows the first transportable super-voltage machine in America. A special mount, designed for the 1 MeV unit, enables the movement of the machine to any site in the shop with a minimum of effort, for use at any angle from the horizontal to the vertical. The company's 1 MeV and 2 MeV Van de Graaff machines are of d.c. design, that is, the beam of the particles generated contains less low-energy radiation, reducing scatter and increasing penetrating power. This characteristic enables thin objects to be radiographed without the obliteration of detail by excessive low-energy radiation. The focal spot of only 0·030in diameter ensures sharp images on X-ray film, enabling small discontinuities to be seen more clearly. The size of the focal spot substantially reduces the distance as well as the longer set-up times required with larger spots. Furthermore, since, with the Van de Graaff machine, the X-ray can be placed close to the objects under study, the size of the room housing the equipment can be held to a minimum, thus materially lowering the overall costs of the installation.

In recent years there has been a notable trend toward the development of relatively light and portable X-ray units to facilitate on-site radiography. A new and representative machine is the "Baltograph 120," which was exhibited by the Balteau Electric Corporation, of Stamford, Connecticut. This machine can be operated at voltages low enough to radiograph spot welds and light materials, yet it is powerful enough to handle moderately heavy work up to its penetration limit of more than 1in of steel. It has a range of 30kV to 120kV and 1mA to 5mA. Because of its lightness and compactness, the unit is exceptionally well fitted for field projects. Portability is combined with excellent sharpness of detail in radiographic inspection. The machine can be brought to the work or permanently or semi-permanently mounted at fixed locations on the factory floor or in the laboratory.

The X-ray tube, oil-immersed high-tension transformers and filament transformers, and automatic-turbine cooling system are enclosed in a steel tank, which is designed to be ray-proof and shock-proof. Maximum penetration and sharpness of detail are ensured by a combination of fine focus (2·3mm by 2·3mm), and a power margin more than adequate for the operating requirements. No cooling pump, special power supply or special accessories are required. The weight of the "Baltograph" X-ray head is 105 lb. The splash-proof metal cabinet of the control unit contains current selectors, meters, a timer that automatically cuts off exposure at the end of a predetermined period, a running time meter and a voltage stabiliser. Its weight is 65 lb.

The use of spot X-ray inspection in place of trepanning is becoming more and more common practice in the inspection of welds, particularly in the American petroleum industry. Spot radiographs of a small area give more information with less effort and without risk of introducing additional defects. This requires the use of very light and portable equipment of low cost, operable by people who have no radiographic training. These conditions are fulfilled by the 140kV "Baltospot" unit, which was also demonstrated by the firm. Its sturdy design was developed to satisfy the conditions in the field. Very light, it can be easily carried up a ladder by one man. At the same time, it is very powerful and easily permits the examination of 1½in thick steel. Devices can be supplied with the unit to position positively the X-ray head at the minimum distance to cover a chosen film area. Because of its very fine focal spot, these units can be used to advantage not only in the petroleum industry, but also in shipbuilding, pressure vessel fabrication, aircraft and light metal industries. The units are suitable not only for work at short focus-film distance, but also for radiography at conventional 36in focus-film distance where a very light, compact and portable unit is required. The X-ray head contains the X-ray tube and transformers inside a shock-proof, waterproof housing. The head will go through a 11in by 15in manhole, and weighs only 46 lb. The control unit is also compact and weather-proof and weighs 23 lb.

Automatic Welding

Another American manufacturer now offering a complete line of automatic welding equipment is the Hobart Brothers Company, of Troy, Ohio. The units exhibited at the Metal Show included a fully automatic submerged arc welding head and control with hopper flux feed, the "Handomatic" semi-automatic submerged arc welding equipment and the particularly interesting "Migarc" inert-gas-shielded arc welding set. The latter equipment is intended for use with consumable electrode wire. It is specially designed to take advantage of the extreme simplicity of controls made possible by the firm's "Powromatic" constant-voltage arc welder. All essential controls of the "Migarc" set are readily at hand, within easy reach and vision of the operator. A hinged door provides accessibility to the wire feed mechanism and wire straightening device. The wire reel support assembly is easily removable by removing the two wing nuts which secure it to the base. Standard equipment with this unit is the so-called "slow wire-feed start circuit," which ensures easy starting in applications involving fast wire-feed speed. A toggle switch is provided, however, to by-pass this circuit for the purpose of saving time in threading wire through the flexible gun cable in preparation for welding. The wire feed control rheostat, which serves as a potentiometer wire speed control and as a dynamic brake, is mounted in a separate rheostat housing on top of the main housing. The remote voltage control rheostat is also contained in this top-mounted housing, which is designed for optimum cooling.

The top-mounted housing can be detached from the main unit, for remote control operation if desired, by merely removing four screws and plugging in a length of six-conductor, rubber-covered control cable, which is optional equipment. The wire feed motor and gearbox are mounted on a fibre insulating board. The assembly is totally enclosed and easily accessible through a door on the rear side. A fan-cooled 110V d.c. shunt motor drives the wire feed mechanism. A ball bearing, double worm gear reduction drives a grooved feed roll, against which the wire is held firmly by a spring-loaded pressure roll. A spring-loaded, knurled screw makes it easy to adjust the tension on the wire, which is fed through a suitable connection to the wire feed tube of the welding gun. As the wire passes through the wire feed mechanism from the coil or spool, a two-roller wire straightener ensures maximum straightening and alignment, with the very least amount of "drag" on the wire. The "Migarc" unit is designed for use with continuous current up to 500A using the following wire sizes :—Hard wires, 0·035in, 0·045in, $\frac{1}{16}$in, $\frac{5}{64}$in and $\frac{3}{32}$in; soft wires, 0·045in, $\frac{1}{16}$in and $\frac{3}{32}$in. The standard wire feed motor gears permit a wire feed speed of 35in to 350in per minute. The basic unit is mounted on a steel base on four ball bearing castors, making it easy to pull the unit along the line of weld in deck welding. This base can easily be removed for taking the unit into places providing small entrance apertures.

(To be concluded)

American Particle Accelerator for Japan.—The first particle accelerator to be built in the United States for use in Japan has been ordered by the Japanese Atomic Energy Research Institute, which is the central organisation for nuclear development work in Japan. The machine is a 2 MeV Van de Graaff accelerator; it will be built by the High Voltage Engineering Corporation, of Cambridge, Massachusetts, and will be equipped for a variety of studies in nuclear physics and engineering. Special targets to be provided will enable the machine to produce X-rays and neutrons, in addition to positive ions and electrons. A beryllium target, when used with positively charged particles to produce neutrons, makes the machine suitable for studies with sub-critical reactor assemblies as well as in activation analysis work. For basic nuclear physics studies a mass stabilising system is to be included, which, when used with positive ions, gives an intense beam of monatomic particles possessing high energy stability.

Personal and Business

Appointments

MR. A. A. THORNBROUGH has been appointed president of Massey-Harris-Ferguson, Ltd., Toronto.

COMMANDER (E) JOHN WHITE, R.N. ret., has been appointed London manager of Peter Brotherhood, Ltd.

MR. H. J. BILLING has been appointed sales manager of Metalastik, Ltd., Evington Valley Road, Leicester.

J. W. ROBERTS, Ltd., Armley, Leeds, 12, announces the appointment of Captain H. Barnet-Lamb as marine technical sales representative.

MR. P. L. JONES, Mr. J. A. Lindsay Keir and Mr. P. N. Lykiardopulo have been elected to the general committee of Lloyd's Register of Shipping.

MR. J. D. STEWART, Mr. Ian W. S. Wilson and Mr A. Augur East have been appointed to the Scottish committee of the Council of Industrial Design.

MR. R. STATON, works manager of Staybrite Works and a special director of Firth-Vickers Stainless Steels, Ltd., Sheffield, has been appointed a director of the company.

MR. F. I. J. PAGE has been appointed manager of the aviation division of S. Smith and Sons (Australia) Pty., Ltd. He succeeds Mr. F. J. Shaw, who has become assistant general manager of the company.

MR. W. C. PATERSON has been appointed chief publicity officer of the Head Wrightson group of companies. His office is at Ship House, 20, Buckingham Gate, London, S.W.1 (telephone, Victoria 6581).

SCOTTS' SHIPBUILDING AND ENGINEERING COMPANY, Ltd., states that Mr. Douglas M. P. Phillips has expressed his desire to retire from the chairmanship and from the board of the company at the end of the year. Mr. M. A. Sinclair Scott has been elected chairman.

MOBIL OIL COMPANY, Ltd., announces the appointment of Mr. R. T. Campbell as general manager of the industrial divisions. He was formerly manager of the company's northern industrial division in Manchester, in which position he has been succeeded by Mr. D. B. Hunt.

MR. TOM BISHOP, F.I.M., is relinquishing his positions as metallurgical editor of *Iron and Coal Trades Review* and editor of *Metal Treatment and Drop Forging* to join the metallurgical staff of John Miles and Partners (London), Ltd., 76, Cannon Street, London, E.C.4.

MR. L. A. WOODHEAD, a director and general manager of Cossor Instruments, Ltd., has been elected chairman of the electrical and electronics section of the Scientific Instrument Manufacturers' Association. Mr. A. E. Evans, managing director of Evans Electroselenium, Ltd., has been elected vice-chairman of the section.

THE GAUGE AND TOOL MAKERS' ASSOCIATION, Standbrook House, 2–5, Old Bond Street, London, W.1, has announced the following elections :—Mr. F. W. Halliwell, M.I.Mech.E., president ; Mr. S. J. Harley, M.I.Mech.E., deputy president ; Mr. A. L. Dennison, Mr. H. S. Holden, and Mr. T. Ratcliffe, vice-presidents ; Mr. L. E. Van Moppes, chairman; Mr. G. P. Barrett and Mr. R. Kirchner, vice-chairmen.

Business Announcements

HEYES AND CO., Ltd., Wigan, has opened a sales depot at 23, Bedford Street, Belfast.

RONALD TRIST AND CO., Ltd., Bath Road, Slough, states that its telephone number will be changed on January 1 to Slough 25041.

GOODENOUGH PUMPS, Ltd., states that its head offices will be moved to its works at Byfleet, Surrey (telephone, Byfleet 4401), on January 1.

THE BUILDING RESEARCH STATION, Bucknalls Lane, Garston, Watford, states that its telephone number has been changed to Garston (Herts) 4040.

THE COPPER DEVELOPMENT ASSOCIATION has moved its headquarters from Radlett, Herts, to 55, South Audley Street, London, S.W.1 (telephone, Grosvenor 8811).

DOULTON AND CO., Ltd., states that it is becoming associated with Mashman Bros. Pty., Ltd., Sydney, and that a new company, entitled Doulton Mashman Pty., Ltd., is being formed.

BRITISH INDUSTRIAL PLASTICS, Ltd., Oldbury, Birmingham, states that " Bipel " hydraulic pelleting machines are to be made by the Logan Engineering Company, Chicago, for sale in the U.S.A.

THE GYPSUM BUILDING PRODUCTS ASSOCIATION has been dissolved and a new association, entitled the Gypsum Plasterboard Development Association, has been formed. Its address is 11, Ironmonger Lane, London, E.C.2.

MR. G. A. MAUNSELL, M.I.C.E., formerly senior partner in the firm of Maunsell, Posford and Pavry, is now practising in partnership with Mr. J. W. Baxter, Mr. E. M. Birkett, Mr. L. M. Ramage, and Mr. P. F. Stott, under the title of G. Maunsell and Partners, 7, Cleveland Row, London, S.W.1 (telephone, Trafalgar 1788).

MR. ERIC SOUTHWELL, who has been employed for the past twenty years as an engineering draughtsman at the Witton works of The General Electric Company, Ltd., is making an inquiry into the use of automation by a number of engineering firms in this country and in Western Europe. This inquiry is sponsored by the European Productivity Agency.

Contracts

FITZPATRICK AND SON (CONTRACTORS), Ltd., has been awarded the first contract for road works in the second stage of the Cromwell Road Extension. It is expected to take 12 months ; it includes the construction of new roads and the widening and improvement of existing roads between Gliddon Road and Hammersmith Road by way of Colet Gardens and Great Church Lane. The works comprise two 30ft carriageways and the construction of a new link between Hammersmith Road and Great Church Lane, with a lay-by. The total estimated cost amounts to £135,650. It is also proposed to widen Great Church Lane Bridge, which carries Great Church Lane over the District and Piccadilly railways just south of Hammersmith Station. The bridge is to be widened by about 35ft to provide an undivided carriageway 50ft wide and two footways each 12ft 6in wide. The widened superstructure is to be constructed in two spans supported by a concrete pier between the railway tracks. Pipe bays will be provided under the new south footway. This work will be carried out by William Old, Ltd., at an estimated cost of £48,658, and is expected to take fifteen months to complete. The total cost, including ancillary works, is estimated at £68,500. The works are under the direction of the London County Council's chief engineer, Mr. J. Rawlinson, C.B.E.

Miscellanea

OPENING OF KELLOGG HOUSE.—On Friday, December 14, the Kellogg International Corporation opened its new offices in Kellogg House, Chandos Street, London, W.1. The Kellogg Company has had representation in the United Kingdom since 1920, but it was not until 1947 that the Kellogg International Corporation was founded to perform the services of engineering contractor for the oil refining and chemical industry in Britain. Part of Kellogg House was built in 1952, but the completion of the six-storey building makes available a floor area of 46,208 square feet to house the various departments of the Corporation.

A CAREER IN CONSTRUCTION.—A new colour film, produced by John Laing and Son, Ltd., 4, Regent Street, London, S.W.1, entitled " Chance for a Lifetime," was shown before an invited audience in London last week. The film outlines some of the many careers open to boys in the building and civil engineering industries, and draws attention to the conditions under which they will work. Details are given of the special facilities offered by the company for training through its Articled Pupils Scheme. This is a comprehensive five-years' scheme and articled pupilship is offered to suitable boys seeking to qualify in quantity surveying, cost surveying, architecture and accountancy. There are also a limited number of vacancies for boys who wish to qualify in civil and mechanical engineering. The film is available in 16mm size.

INSTITUTE OF MARINE ENGINEERS.—A paper with the title " Reheating as a Contribution of the Economy of the Marine Steam Turbine, with Special Reference to the Installation in T.S.S. ' Empress of Britain,' " was presented by Mr. A. W. Davis, B.Sc., before the Institute of Marine Engineers on November 13. The paper describes the system of gas reheating developed and applied to the twin-screw turbine installation in T.S.S. " Empress of Britain." After considering the fuel consumption ratio applying to alternative straight cycle designs, a description is given of the basic development of design with reheating, together with a diagrammatic arrangement of the Fairfield system. The main machinery is also described with the aid of photographs, general arrangement and detail drawings. Attention is directed to particular features in the operation of the machinery and details given of the service results, including a table giving the boiler heat balance and another table giving data relative to the comparison of the ship's performance with some earlier liners. The weight ratio of the machinery installation is given as 13·4 s.h.p. per ton and the fuel consumption, for propulsion only, as 0·495 lb per shaft horsepower per hour. The paper concludes with a brief reference to future possible development in reheating, together with some notes on the thermodynamics of the subject.

NICKEL PLATING FOR ENGINEERS.—A new publication entitled " Nickel Plating for Engineers," which has been issued by the Mond Nickel Company, Ltd., is intended primarily for engineers, designers and others who are interested in the possibilities which plating offers in design. The book is not designed to cover plating procedures in great detail but it deals with practices in so far as they affect the properties of the resultant deposits. The text includes a description of surface preparation in general and for zinc-base alloys, aluminium and nickel-chromium-iron alloys in particular. Concise details are given of commonly used solutions, relevant plating procedures to maintain high quality work, plant required, mechanical properties of deposits and the methods of testing deposits. Copies of the publication are obtainable free of charge from the firm's publicity department, Thames House, Millbank, London, S.W.1.

ELECTRIC FURNACE ELEMENTS.—A silicon carbide element for electric furnaces is now being made by the Morgan Crucible Company, Ltd. These " Crusilite " elements, as they are known, are stated to be capable of being operated at temperatures up to 1575 deg. Cent. They are of one-piece silicon carbide construction and in them the central hot zone is in the form of a spiral of the requisite length. Five diameters of the elements are available—10mm, 14mm, 18mm, 22mm and 28mm—with a range of hot zone and overall lengths to suit different designs of furnaces. The 10mm and 14mm sizes have special metal terminal caps shrunk on to the metallised ends, which ensure a good electrical contact to the silicon carbide and provide an easy means of connecting them to the power supply. It is stated that the method of manufacture permits the maintenance of a resistance tolerance of ±10 per cent of nominal and where elements are supplied as a set for a particular furnace the resistance of individual elements will not vary by more than ±5 per cent of the mean. A " Crusilite " element will shortly be available with a hot zone formed by two parallel spirals, so that both electrical connections can be made at the same end.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—On November 30, Mr. T. M. Norén, M.Sc., read his paper, " The Nominal Cleavage Strength of Steel and its Importance for Welded Structures," before the North East Coast Institution of Engineers and Shipbuilders. The paper states that a certain property of steel called the " nominal cleavage of strength " can be determined by means of tensile test pieces on the edges of which a brittle alloy has been welded, and that exposure of these test pieces to an increasing tensile stress causes cracks to be formed continuously in the brittle layers of welding. At a critical stress a fracture will be initiated at one of the sharp crack fronts. This nominal cleavage strength is defined, in the paper, as the highest nominal tensile stress a steel can withstand in the presence of a crack without the initiation of fracture at the crack front. The cleavage strength decreases as temperature decreases just as the yield point increases with decreasing temperature and it is noted that the point of intersection of these strength curves appears to be a transition temperature for the steel. This is defined as the temperature above which plastic deformation can occur in a large volume of material despite the presence of a crack but below which only minor local plastic deformation is possible immediately in front of the crack. Results obtained by means of a method called " NC-testing " are stated to show a certain correlation to those of impact tests as well as those of brittle fracture tests. Moreover, the critical stresses for initiation and propagation of brittle fractures are shown by means of N.C. (nominal cleavage) curves as well as the influence of residual welding stresses. It is also shown that the quality of a steel, with regard to its brittle fracture tendency, cannot be expressed by an impact transition temperature, as the critical stresses quoted above are not directly connected with the position of this temperature.

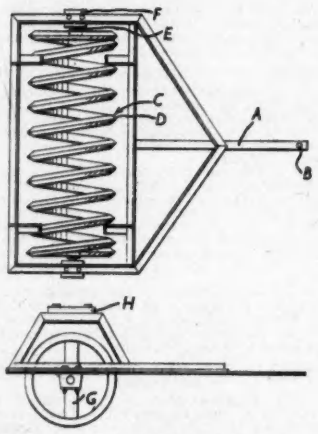
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

AGRICULTURAL ENGINEERING

761,217. December 13, 1954.—AGRICULTURAL IMPLEMENTS, Emerson Hilton Summach, 706, 3rd Street, Saskatoon, Saskatchewan, Canada. (*Inventors: Harvey Wesley Summach and Emerson Hilton Summach.*)

The invention relates particularly to an agricultural implement for compacting surface soil. As shown in the drawing, the apparatus has a resiliently flexible compacting member which is formed from an elongated strip of slightly flexible material having a triangular cross-sectional shape. This strip is formed as a spiral coil having a relatively long pitch



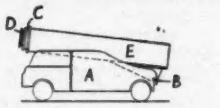
No. 761,217

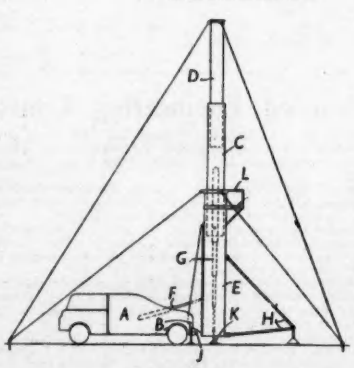
which is optional within certain limits. The coil has a ground-engaging ridge on it which produces a generally V-shaped groove in the ground surface, although the invention is not limited to a traingular cross-section shape. A weight carrying superstructure is provided by two upstanding supporting bay frames interconnected by a suitable cross platform. This cross member also serves to permit attachment of another implement behind the compacting apparatus. The weight of the compacting apparatus may be increased by mounting sand bags or the like on the cross member. The general construction of the compacting apparatus is relatively light and this is of material advantage when operating on extremely soft ground where little weight is required.—*November* 14, 1956.

ROAD TRANSPORT

760,067. June 8, 1954.—TELESCOPICALLY EXTENSIBLE TOWERS, The Eagle Engineering Company, Ltd., Eagle Works, Warwick. (*Inventor: Dennis Guy Palmer.*)

The invention refers to improvements in telescopically extensible towers, and has particular reference





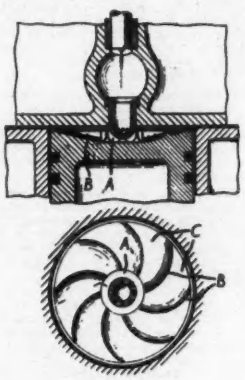
No. 760,067

to a tower which is mounted on and combined with a vehicle. As the drawing shows, the invention comprises a road vehicle *A* on which is mounted by means of a pair of trunnions *B* a three-part tower, the upper parts *C* and *D* being adapted to be telescoped within the base *E*. The base of the tower is pivotally connected to a pair of hydraulic rams *F* anchored at their lower end within the body of the vehicle. Another hydraulic ram *G* within the base of the tower connects it to the upper part *C* to give the required extension. Normally the telescoped tower lies in a cradle on the top of the vehicle and can be moved in its collapsed form to a vertical position when the base part is stabilised on the vehicle and on the surrounding ground surface by struts *H* which can form a tripod mounting for the lower base part *E*, screw jacks *J* being employed as feet for the tower to permit level setting. The base *E* is provided with a ball and socket adjustable jack mounting *K* to assist in centralising and accurately positioning the tower. The tower is adapted to support equipment for use in radio or television transmission and on the lower section *E* there is a pivotally mounted platform *L* for the operator.—*October* 31, 1956.

INTERNAL COMBUSTION ENGINES

760,860. July 12, 1954.—INTERNAL COMBUSTION ENGINES, Daimler-Benz Aktiengesellschaft, Stuttgart-Unterturkheim, Germany.

The invention relates to internal combustion engines for motor vehicles, but it can also be applied to other types of engine. It will be seen from the drawing that in a combustion chamber type of engine, with a main combustion chamber bounded by the piston head, the head is provided with spirally curved formations, by which the air compressed in the chamber is whirled and therefore mixed with the fuel injected directly or indirectly into the chamber. As shown, the nozzle

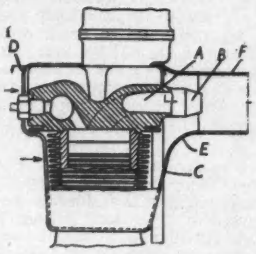


No. 760,860

from the combustion chamber projects into the main combustion chamber when the piston is at the top of its stroke, a central hollow space being provided for it. Radiating from this space *A* are a series of fins *B* the height of which is such that their top edges lie level with the rim of the piston head and so cause whirling of the air compressed within the combustion chamber. As seen in plan in the lower view, the fins are curved spirally, and an outlet opening from the nozzle is advantageously allotted to each of the spiral sectors *C* lying between the fins. These sectors gradually become shallower towards the periphery of the piston, but at the same time their width increases so that they finally merge into the flat rim of the piston head. A modified design mainly intended for the smaller engines shows the arrangement when the precombustion chamber is placed eccentrically to the axis of the cylinder.—*November* 7, 1956.

761,427. December 1, 1954.—COOLING AIR-COOLED ENGINES, Ferdinand Porsche, personally responsible partner of the firm of Dr.-Ing. h.c.F. Porsche, K.G., Neckarsulmer Strasse 85, Stuttgart-Zuffenhausen, Germany.

The invention relates to cooling arrangements for air-cooled internal combustion engines in which the cooling air guided by a sheet metal jacket is impelled over the cylinder and cylinder head cooling ribs by an ejector action of the exhaust gases. As shown in the drawing, on the opposite side of the cylinder head to the injector is an exhaust gas conduit *A* which merges into the exhaust nozzle *B*. The cylinder head is cast integrally with the exhaust nozzle. For guiding the air, both the cylinder and the cylinder head are jacketed with air-guiding metal sheets *C*. On the air intake side the jacket is not closed off as is usual when a blower impels the air, but terminates on the front of the cylinder, in such a way as to leave free a wide air gap *D*. A still wider air gap is provided on the cylinder head. The widths of the air gaps are preferably of such a size as to leave unobstructed the entire cooling air intake side of the cylinder head and cylinder proper. On the opposite side of the cylinder and cylinder head the jacket terminates in the vicinity of the exhaust nozzle in a part *E*, to which a mixing tube *F* is attached. The



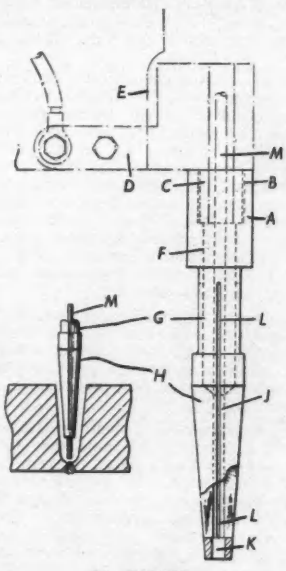
No. 761,427

exhaust gases pass next from the mixing pipe into a diffuser. During engine operation the exhaust gases pass through the exhaust gas conduit *A* in the cylinder head into the nozzle and further on into the mixing tube. Due to the suction action of the exhaust gases, the air is sucked through the gap *D* between the cooling ribs of the cylinder and cylinder head substantially without a change in direction.—*November* 14, 1956.

WELDING APPLIANCES

761,325. November 10, 1954.—HOLDERS FOR WELDING ELECTRODES, The English Steel Corporation Ltd., River Don Works, Sheffield, 9. (*Inventor:, Bernard Thomas Ballington.*)

The invention relates to holders for welding electrodes, particularly, but not exclusively, applicable for use in machine welding with a "continuous" electrode. As will be seen from the drawing, the holder comprises a head *A* tapped at *B* to receive a screwed boss *C* on a combined mechanical mounting and electrical contact member *D* carried by a part *E* of the welding machine. The head has a wide bore *F* that continues through a neck *G* and ends in the upper end of a tapered portion *H*



No. 761,325

A smaller bore *J* continues through the portion *H* and emerges into a slightly larger bore *K*. From the inner end of the bore *K*, four slits *L* extend along the portion and into the neck. A "continuous" electrode *M* fed through the mounting *D*, the boss *B*, and the wide bore *F* is forced into the narrow bore *J* and is gripped resiliently over the length occupied by the slits *L*, the diameter of the bore *J* being appropriate to the diameter of the electrode, after making allowance for roughening of the electrode by the feed-wheels of the machine. Good electrical contact is made over this length, which enables welding to proceed with the current and voltage held to very steady values. As shown in the left hand view, the portion *H* may be introduced deep into the angular notch produced by the edge formation of two parts to be welded together, so that the protruding portion of the electrode may be supported close to the bottom of the notch that has been completed by the preliminary run of welding. Consequently, there is avoided the disadvantage of a long length of highly heated electrode ploughing through the depth of flux that has been poured into the notch in advance of the holder.—*November* 14, 1956.

Launches and Trial Trips

SUNVICTOR, closed shelter deck cargo ship ; built by the Burntisland Shipbuilding Company, Ltd., for Skibs A/S "Geirulv," Norway ; length overall 475ft, length between perpendiculars 450ft, breadth 62ft 9in, depth moulded to upper deck 38ft 6in, draught 29ft, deadweight 12,500 tons ; three 220kW diesel-driven generators ; one set of geared turbines, 5000 service s.h.p. at 115 propeller r.p.m., two Babcock and Wilcox water-tube boilers supply steam at 475 lb per square inch and 760 deg. Fah. Launch, November 19.

TENNYSON, cargo ship ; built by Henry Robb, Ltd., for the Chine Shipping Company, Ltd.; length between perpendiculars 335ft, breadth moulded 50ft, depth moulded to upper deck 26ft 6in, deadweight 5500 tons on 21ft 10in mean draught ; service speed 11 knots ; two large holds, electric-hydraulic winches, eight 5-ton derricks ; three 106kW diesel-driven generators ; Sulzer diesel engine, 2000 b.h.p. at 155 r.p.m. Launch, November 20.

STORFONN, oil tanker ; built at Belfast by Harland and Wolff, Ltd., for Sigval Bergesen, Stavanger ; length overall 660ft, length between perpendiculars 640ft, breadth moulded 86ft, depth moulded 51ft 6in, deadweight 34,900 tons ; thirty cargo oil tanks, ten 'tween deck ballast tanks, one main cargo pump room ; two 800kW, 440V, 60 c/s turbine-driven, alternators, two 250kW diesel-driven alternators, one 25kW diesel-driven emergency alternator ; one set of compound double reduction geared turbines, 12,500 service s.h.p. at 112 propeller r.p.m., two oil-fired Babcock and Wilcox water-tube boilers supply steam at 450 lb per square inch and 750 deg. Fah. Launch, November 20.

HAMINELLA, oil tanker ; built by Smith's Dock Company, Ltd., for Shell Tankers, Ltd.; length overall 557ft, length between perpendiculars 530ft, breadth moulded 69ft 3in, depth moulded 39ft, deadweight 18,000 tons on 29ft 6in draught, service speed 14½ knots ; thirty-three main cargo oil tanks, one main cargo pump room, four 400 tons per hour turbine-driven cargo pumps, two stripping pumps ; two 550kW turbine-driven alternators, one 200kW diesel-driven alternator ; one set of Hawthorn Leslie two casing, double reduction geared turbines, two Foster-Wheeler "D" boilers supply steam at 500 lb per square inch and 800 deg. Fah. Launch, November 20.

PORT LAUNCESTON, cargo liner ; built at Belfast by Harland and Wolff, Ltd., for the Port Line, Ltd.; length overall 490ft, length between perpendiculars 460ft, breadth moulded 65ft 6in, depth moulded to upper deck 41ft 6in, gross tonnage 8400 ; ten passengers ; three complete steel decks, seven watertight bulkheads, five main cargo holds, one 70-ton, four 15-ton, four 10-ton, six 5-ton derricks, and one 3-ton electric crane ; three 360kW diesel-driven generators ; Harland and Wolff two-cycle, single-acting, opposed piston oil engine, seven cylinders, 750mm diameter by 2000mm combined stroke, 112 r.p.m. Launch, November 21.

T.I.C. No. 27, hopper barge ; built by William Simons and Co., Ltd., for the Tyne Improvement Commission ; length 144ft, breadth 31ft, depth 13ft 9in, counterbalanced masts ; capacity 600 tons ; Widdop six-cylinder, two-cycle diesel engine. Launch, November 22.

WOODARRA, cargo liner ; built by Barclay, Curle and Co., Ltd., for the British India Steam Navigation Company, Ltd.; length 520ft, breadth 68ft 3in, depth to shelter deck 42ft 3in, gross tonnage 10,000 ; five cargo holds, twenty derricks, electric winches ; four 300kW diesel-driven generators ; one set of double reduction geared two-casing turbines, 112 propeller r.p.m., steam supplied at 500 lb per square inch and 800 deg. Fah. by two integral furnace boilers. Launch, November.

DJUNGO, banana carrier ; built by the Chantiers de Provence for Messrs. L. Martin, length overall 367ft 5¼in, length between perpendiculars 341ft 2in, breadth moulded 49ft 3in, depth to upper deck 36ft 11in, draught loaded 19ft ; four holds, capacity 176,550 cubic feet, speed 16 knots ; bipod masts, three continuous decks, electric winches ; three Freon 12 compressors, three 240kW diesel-driven generators ; one Provence-Doxford oil engine, five cylinders, 5100 h.p. at 140 r.p.m. Trial, November.

WAVE CREST, cargo liner ; built by the Forges et Chantiers de la Mediterranée at La Seyne for the Crest Shipping Company of Nassau (Bahamas) ; length overall 476ft 2¼in, length between perpendiculars 442ft, breadth moulded 61ft 6in, depth to shelter deck 39ft 6in, draught loaded 26ft 6in (open shelter), 30ft (closed shelter), corresponding deadweights 10,750 tons and 13,000 tons ; trial speed 15 knots ; five holds, grain capacity 675,300 cubic feet, one 50-ton, one 40-ton, six 10-ton, and four 5-ton derricks ; electric winches, three 250kW diesel-driven generators, one 30kW diesel-driven emergency generator ; Sulzer 8 SD.72 diesel engine, 5600 h.p. at 125 r.p.m. Trial, November.

Catalogues and Brochures

THE NYLONIC ENGINEERING COMPANY, Ltd., 7, The Meadow Way, Wealdstone, Middlesex.—Catalogue giving details of nylon rod, tube and sheet available.

SHARPLES CENTRIFUGES, Ltd., Tower House, Woodchester, Stroud, Glos.—Revised bulletin dealing with "Super Purification of Heavy Fuel Oil for Diesel Engines" (No. 2556).

S. RUSSELL AND SONS, Ltd., Bath Lane, Leicester.—Booklet entitled "S.G. Iron : The New Engineering Material," which can be read in conjunction with the first British Standard for S.G. iron, B.S. 2789 : 1956.

THE NORTH EASTERN MARINE ENGINEERING COMPANY, Ltd., P.O. Box No. 2, Wallsend, Northumberland.—Publication giving details of superheaters, together with examples of their successful application. Inquiries for the conversion of existing plant or proposed new plant are invited.

SOLUS-SCHALL, Ltd., 15–18, Clipstone Street, London, W.1. Catalogue giving technical details of non-destructive testing by the use of X-rays, gamma-rays, ultrasonics, magnetic and eddy current methods and penetrants. Illustrations show typical examples of materials under inspection.

THE BRITISH ELECTRICAL DEVELOPMENT ASSOCIATION, 2, Savoy Hill, London, W.C.2.—Illustrated booklet giving details of electrical appliances used to maintain cleanliness in the handling of food, with special reference to the Food Hygiene Regulations made under the Food and Drugs Act, 1955.

THE HYMATIC ENGINEERING COMPANY, Ltd., Redditch, Worcestershire.—Illustrated book entitled "Air is in the Air," giving an outline of the "Hymatic" resources for technical development and precision manufacture. Details are given of compressed air equipment developed for the aircraft industry.

THE PLESSEY COMPANY, Ltd., Kembray Street, Swindon, Wiltshire.—A catalogue containing data on the range of "Standard" plugs and sockets manufactured by the Plessey Company of special interest to engineers and designers concerned in the operation or planning of equipment using these plugs and sockets.

THE SPENCER WIRE COMPANY, Ltd., Wakefield, Yorkshire.—Illustrated brochure giving details of the history and development of the company, which this year celebrates its golden jubilee. The works at Wakefield and the machinery and equipment used are described. Mention is also made of plans for the future.

THE VISCO ENGINEERING COMPANY, Ltd., Stafford Road, Croydon, Surrey.—Publication No. 562, describing air filters of the standard oil-wetted type. This filter is supplied in two principal forms, the "Standard" type, for ordinary commercial use, and the "Duplex" type, for use where a very high degree of filtering efficiency is necessary.

HEAD WRIGHTSON PROCESSES, Ltd., Teesdale House, 24/26, Baltic Street, London, E.C.1.—Brochure entitled "Plant Construction Services," giving details of some of the services and equipment offered to the petro-chemical, chemical and atomic industries, in addition to the petroleum industry. Photographs illustrate some typical installations.

GENERAL ELECTRIC COMPANY, Ltd., Magnet House, Kingsway, London, W.C.2.—Publication surveying the export of electrical equipment and describing some of the recent export achievements of this company. The booklet is divided into seven sections dealing with electrical plant and machinery, domestic equipment, heating and ventilation, communication equipment, cables, lighting equipment and electrical instruments.

THE YALE AND TOWNE MANUFACTURING COMPANY, British Materials Handling Division, Wednesfield, Wolverhampton.—Leaflet No. 1570, describing and illustrating "Gooseneck" boom attachments for use in place of forks on Yale fork lift trucks. This boom is used to handle materials which are not readily palletised due to size or shape, as well as for lifting loads that require reaching over obstacles.

SILVERTOWN RUBBER COMPANY, Ltd., Herga House, Vincent Square, London, S.W.1.—Booklet entitled "The Inside Story of Silvertown Rubber and Ebonite Linings and Coverings." Problems arising from the handling of corrosive and abrasive materials are discussed and some of the methods of protecting tanks, vessels and pipes are explained. A table is included giving details of the chemical resistance of rubber and ebonite to a wide variety of materials.

THE TELEGRAPH CONSTRUCTION AND MAINTENANCE COMPANY, Ltd., Telcon Works, Greenwich, London, S.E.10.—Catalogue dealing with armoured plastic cables. The C.M.A. standard cables listed in this catalogue are made and tested in accordance with the standards and formulæ of the Cable Makers' Association, and comply with the relevant British Standard Specification. In this catalogue each type of C.M.A. cable has an individual reference number common to all members of the Cable Makers' Association.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH INTERPLANETARY SOCIETY

Sat., Jan. 5.—Caxton Hall, Caxton Street, London, S.W.1, "Astronomy and Earth Satellites," Michael W. Ovenden, 6 p.m.

ILLUMINATING ENGINEERING SOCIETY

Tues., Jan. 1.—BIRMINGHAM CENTRE : College of Technology, Suffolk Street, Birmingham, Display of Lighting Fittings, 6 p.m.

Thurs., Jan. 3.—CARDIFF CENTRE : S. Wales Electricity Board's Demonstration Theatre, The Hayes, Cardiff, "Streetlighting and South Wales," F. H. Pulvermacher ; "Eye Appeal," W. G. Sweet, 7 p.m.——NOTTINGHAM CENTRE : Electricity Service Centre, Smithy Row, Nottingham, "Lighting of Standard Factories on Trading Estates," J. S. McCulloch, 5.30 p.m.

INCORPORATED PLANT ENGINEERS

Wed., Jan. 2.—SOUTHERN BRANCH : Polygon Hotel, Southampton, "Ship Construction," 7.30 p.m.

Thurs., Jan. 3.—PETERBOROUGH BRANCH : White Lion Hotel, Church Street, Peterborough, "Dust Control," R. J. Pitt, 7.30 p.m.

INSTITUTE OF METALS

Thurs., Jan. 3.—BIRMINGHAM LOCAL SECTION : Exchange and Engineering Centre, Stephenson Place, Birmingham, Discussion on "Timber versus Metals," opening speakers D. O. Reece, W. E. Ballard and Dorothy Pile, 6.30 p.m.——LONDON LOCAL SECTION : 17, Belgrave Square, London, S.W.1, "The Metallurgical Challenge of Nuclear Power," H. K. Hardy, 6.30 p.m.

INSTITUTE OF PETROLEUM

Wed., Jan. 2.—26, Portland Place, London, S.W.1, Symposium on Staff Training, 5.30 p.m.

INSTITUTE OF REFRIGERATION

Thurs., Jan. 3.—JOINT MEETING : Junior Institution of Engineers, Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "The Thermal Properties of Heat Insulation at Low Temperatures," M. J. Hickman, 5.30 p.m.

INSTITUTE OF TRANSPORT

To-day, Dec. 21.—TEES-SIDE SECTION: Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, "Productivity in Transport : Industrial Transport," D. J. Wilkinson ; "Road Transport," D. S. Deacon ; "Docks," E. Halder ; "Railways," S. H. Giles, 7 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Jan. 8.—ROAD MEETING : Great George Street, Westminster, London, S.W.1, "Organisation and Control of Highways Maintenance," W. J. Hiscock, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., Jan. 7.—S. MIDLAND CENTRE : James Watt Memorial Institute, Great Charles Street, Birmingham, "Recruitment to the Engineering Profession," 6 p.m.

Tues., Jan. 8.—MEASUREMENT AND RADIO SECTION : Savoy Place, London, W.C.2, "A Theoretical and Experimental Investigation of Anisotropic-Dielectric-Loaded Linear Electron Accelerators," R. B. R.-Shersby-Harvie, L. B. Mullett, W. Walkinshaw, J. S. Bell and B. G. Loach, 5.30 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

Mon., Jan. 7.—N.E. COAST BRANCH : Institute of Mining and Mechanical Engineers, Neville Street, Newcastle upon Tyne, 1, "Some Notes on the Choice of Mechanical Stokers for Boiler Plants," E. J. C. Macdonald, 6.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

Wed., Jan. 2.—APPLIED MECHANICS GROUP DISCUSSION : 1, Birdcage Walk, Westminster, London, S.W.1, "New Techniques in Photo-Elasticity," 6.45 p.m.——MIDLAND GRADUATES' SECTION : W. Midlands Gas Board, Darlington Street, Wolverhampton, "Heavy Haulage and its Ancillary Work," E. Bulgin, 7.30 p.m.

Thurs., Jan. 3.—WESTERN A.D. CENTRE : Royal Hotel, Bristol, Film Evening, 6.45 p.m.——YORKSHIRE GRADUATES' SECTION : Mining Lecture Theatre, The University, St. George's Square, Sheffield, "Patenting an Invention," C. Lees, 6.30 p.m.

Fri., Jan. 4.—GENERAL MEETING IN CONJUNCTION WITH THE APPLIED MECHANICS' GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, "An Experimental Investigation of the Process of Expanding Boiler Tubes," J. M. Alexander and Hugh Ford, 6 p.m.

Tues., Jan. 8.—AUTOMOBILE DIVISION GENERAL MEETING IN CONJUNCTION WITH THE HYDRAULICS GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, "A Review of Hydro-Kinetic Fluid Drives and their Possibilities for the British Motor Industry," J. G. Giles, 6 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Mon., Jan. 7.—ORDINARY MEETING : Institution of Electrical Engineers, Savoy Place, London, W.C.2, "Auto Exch. Maintenance Procedure : Past, Present and Future," S. Rudeforth, K. S. Laver and E. R. Driver, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Thurs., Jan. 3.—READING SECTION : Social Club, Petters, Ltd., Staines, "Application of Accurate Measurement to Engineering Production," J. Loxham, 7.30 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Fri., Jan. 4.—WESTERN COUNTIES BRANCH : New Engineering School, The University, Bristol, "The Advantages and Disadvantages of Structural Steelwork, Reinforced Concrete and Prestressed Concrete," Donovan H. Lee, 6 p.m.

INSTITUTION OF THE RUBBER INDUSTRY

Thurs., Jan. 3.—SOUTHERN SECTION : The University, Southampton, "Block Polymer Production by Mechanical Energy," W. F. Watson, 7.30 p.m.

Mon., Jan. 7.—N.E. SECTION : Eldon Grill, Grey Street, Newcastle, Film Evening, 7 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Dec. 21.—INFORMAL MEETING : Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "The J.I.E.: Past, Present and Future," J. Foster Petree, 7 p.m.

Wed., Jan. 2.—MIDLAND SECTION : James Watt Memorial Institute, Great Charles Street, Birmingham, Chairman's Address, J. H. Price, 7 p.m.

Thurs., Jan. 3.—N.W. SECTION : Reynolds Hall, College of Technology, Manchester, "Projection Television Receivers," I. Somers, 6.30 p.m.

Fri., Jan. 4.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, Film Evening, 7 p.m.

PLASTICS INSTITUTE

Wed., Jan. 2.—LECTURE FOR YOUNG PEOPLE : Church House, Westminster, London, S.W.1, "Plastics and the Engineer," J. Butler, 2.30 p.m.

ROYAL AERONAUTICAL SOCIETY

Thurs., Jan. 3.—YOUNG PEOPLE'S LECTURE : Royal Society of Arts, John Adam Street, London, W.C.2, "Experiences of an Airline Pilot," O. P. Jones, 3 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

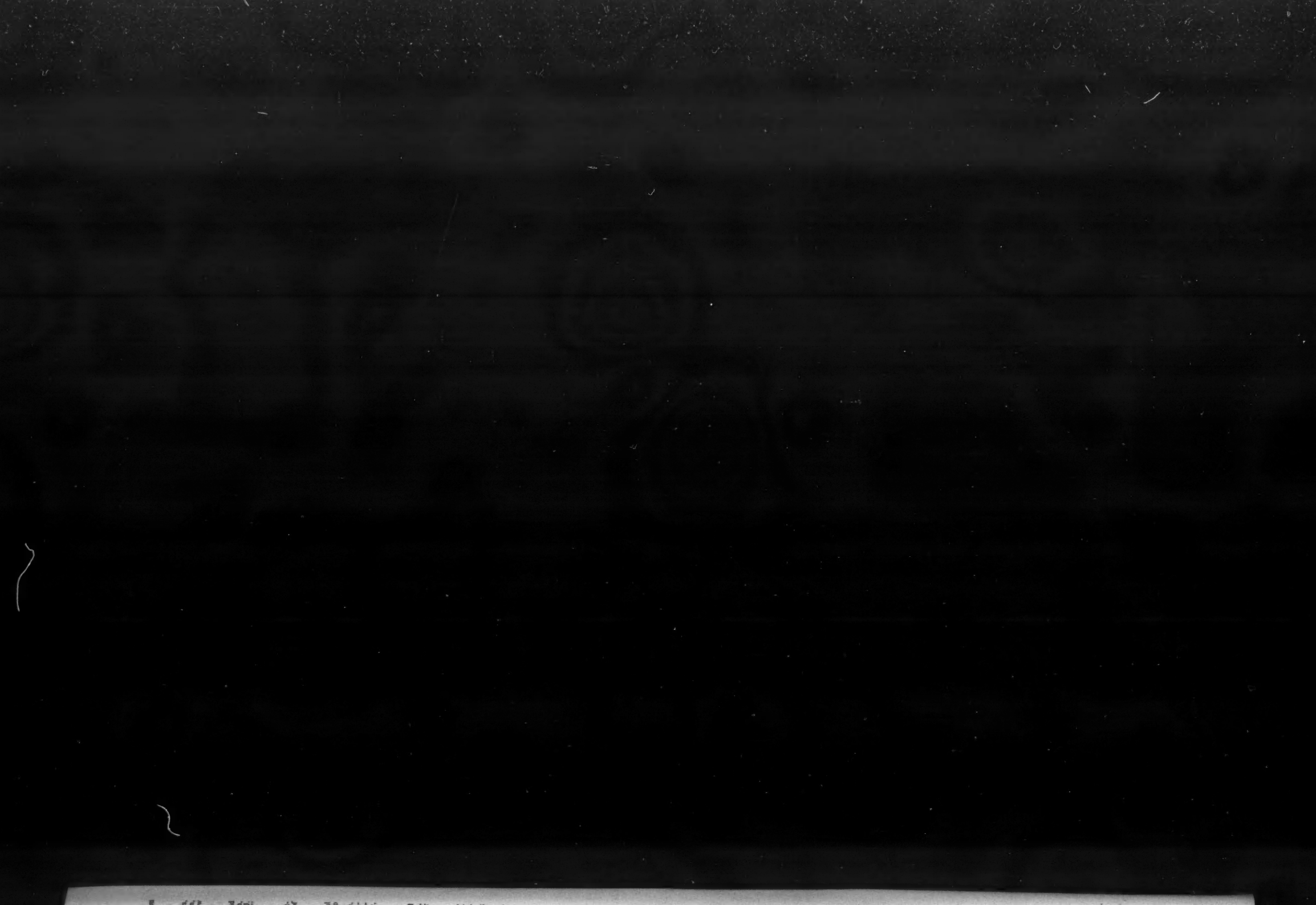
Mon., Jan. 7.—ORDINARY GENERAL MEETING : 12, Great George Street, London, S.W.1, "The Heating of Buildings by Warm Air," W. Davidson, 5.45 p.m.

Advanced Engineering Courses

Organisation of Civil Engineering Contracts. By D. H. GLADWYN. Battersea Polytechnic, London, S.W.11. Course of eight lectures commencing January 14. Mondays from 6.45 p.m. to 8.45 p.m. Fee £1.

Highway Bridge Design. By G. LITTLE. Battersea Polytechnic, London, S.W.11. Course of ten lectures commencing January 15. Tuesdays from 6.45 p.m. to 9 p.m. Fee £1.

Theory and Design of Shell Roofs. By A. GOLDSTEIN and P. B. MORICE. Battersea Polytechnic, London, S.W.11. Course of eight lectures commencing January 16. Wednesdays from 6.45 p.m. to 9 p.m. Fee £1.

Plastic Design of Steel Structures. By E. GOODWIN and W. T. LAWTON. Battersea Polytechnic, London, S.W.11. Course of eight lectures commencing January 17. Thursdays from 6.45 p.m. to 9 p.m. Fee £1.

Structural Design in Aluminium. By R. M. DAVIES and J. B. DWIGHT. Battersea Polytechnic, London, S.W.11. Course of six lectures commencing January 14. Mondays from 7 p.m. to 9 p.m. Fee 10s.